Jean Macé

75

Charles Lanman

THE

SERVANTS OF THE STOMACH.

BY JEAN MACÉ,

AUTHOR OF

"THE HISTORY OF A MOUTHFUL OF BREAD," "HOME FAIRY TALES,"

ETC., ETC.

REPRINTED FROM THE LONDON TRANSLATION, REVISED AND CORRECTED.

NEW YORK:

HARPER & BROTHERS, PUBLISHERS,

FRANKLIN SQUARE.

1868.

By JEAN MACÉ.

HOME FAIRY TALES (*Contes du Petit-Château*). Translated by MARY L. BOOTH. With Engravings. 12mo, Cloth, $1 75.

THE SERVANTS OF THE STOMACH. Reprinted from the London Translation, Revised and Corrected. 12mo, Cloth, $1 75.

THE HISTORY OF A MOUTHFUL OF BREAD: and its Effect on the Organization of Men and Animals. Translated from the Eighth French Edition by Mrs. ALFRED GATTY. 12mo, Cloth, $1 75.

THE HISTORY OF THE SENSES AND THOUGHT. Translated by MARY L. BOOTH. 12mo. (*In Press.*)

PUBLISHED BY HARPER & BROTHERS, NEW YORK.

TRANSLATOR'S PREFACE.

M. Macé's books are now so well known to those interested in the education of children, that, in offering this translation to the public, I feel that my best hope of success rests on his name.

It is about two years since Mrs. Gatty's able pen presented our English children with a translation of "Une Bouchée de Pain," under the title of "A Bit of Bread."

The "Bit of Bread," though complete in itself, forms the first of a "Series of Letters to a Child on the Life of Man and Animals," each of which in its turn embraces a higher and more extended range of natural history. First, we began with "The history of life, as sustained and supported in the human race." We next studied "The history of life in the lower animals;" now we come to man himself, God's greatest, noblest work. We trace his exquisite structure, his wonderful superiority over the lower forms of animal life, and, taking the stomach as the centre of the vital system, we care-

fully review the greater number of its band of servants, and study the various duties assigned to each, for "How knoweth discontented man what a train of ills might follow, if the lowest menial of nature knew not her secret office?"

Entering as heartily as Mrs. Gatty does into the charm of M. Macé's style, and, as she justly observes, "admiring with what marvellous ingenuity and beautiful skill he has brought the great leading anatomical and physical facts of life out of the depths of scientific learning, and made them comprehensible to a child," I have endeavored to follow in her steps, and to render the English edition as nearly as possible in the spirit of the original, suppressing one or two short passages unsuited to English taste, or which would have lost their character in the translation.

Many persons will probably smile when they discover that "The Little Kingdom," is a translation of "Les Serviteurs de l'Estomac," but few will guess how greatly the selection of the title perplexed me. We, in this country, are somewhat fastidious in allusions to the subject of *l'Estomac*, yet so much in the first chapter depends upon the French title that I could not entirely dismiss the obnoxious term. From those, then, who would disapprove, I claim indulgence, in consideration of the amount of valuable information the book contains.

These subjects are new to our young people, but not on that account the less important. This is an advancing age. Happy they who are enabled to combine instruc-

tion with amusement, to awaken in a child's mind a thirst for information, a love for subjects worthy of study, and who teach them that the servants of our material body do not merely minister to our animal wants, but also to the cultivation of the intellect, and to the gratification of the perception of beauty.

The study of the works of the Creator is as elevating as it is delightful, for the more deeply we accustom ourselves to search into the wonders around us, the more clearly we discover the wisdom which is displayed even in the lowest forms of creation.

> "Search out the wisdom of nature, there is a depth in all her doings;
> Oh, frozen is thy heart if it glow not with gratitude for all things;
> In the perfect circle of creation not an atom could be spared,
> From earth's magnetic zone to the bindweed round a hawthorn."

Like Mrs. Gatty, I also am greatly indebted to an able medical friend, who not only first suggested my undertaking the translation of "Les Serviteurs," but with an accurate knowledge of both languages, materially assisted me by his revisal of the MS. Any success my little book may obtain will therefore in great part be due to him, as without his aid these pages would never have been sent to press.

CONTENTS.

THE

SERVANTS OF THE STOMACH.

CHAPTER I.

INTRODUCTION.

My dear child, I have already related in my history of a "Mouthful of Bread," a portion of your own history, that which is going on within you in silence and obscurity, without your thinking about it, without your being even conscious of it; and during most of this time you have been obliged to take me at my word.

What remains for me to speak about now is less mysterious: that is, your arms, your legs, your little nose, your large eyes which are staring at me, your ears which listen to me—all those things which are your constant companions, and the history of which ought, it seems to me, to interest you still more.

All these belong to the walking machine, which is the companion of our eating machine.

You are grown taller and wiser since we began to study together. You are no longer the little girl that knew nothing, and I no longer require to speak to you as I should to a little child. We will therefore lay aside the terms walking and eating machines, which did very well for a beginner, but which are not so good as those

used by scientific men, though they were prettier and more suited to you at first. In science, as elsewhere, the prettiest is not always the best.

This eating machine we ought properly to have called the nourishing machine. To nourish one's self is to change into one's own substance those foreign ingredients which enter into the body, and eating is only the beginning of this grand operation. Self-nourishment is a book of which eating is the introduction. Recollect all the journeys our mouthful of bread took. Once eaten, through how many organs it passed—stomach, heart, lungs, veins, arteries, and the like! All these organs combined to perform a single act—the act of nutrition; and nothing is simpler or clearer than the name given them by scientific men—viz.,

ORGANS OF NUTRITION.

It is the same with the walking machine. Its principal duty, and the only one with which we shall occupy ourselves, is to provide the eating machine with substances on which it must work. To make hare soup, your mother's cookery book tells you, "you must first catch your hare." This is the primary condition imposed on every cook, and on Mr. Stomach as well as other cooks; and to catch the hare, assistants are necessary. Many of our organs act the same part toward the stomach in this preliminary operation without which nutrition is impossible, and these organs are not used for walking only; they are intended, each in its own way, to put us in relation, in connexion, if you prefer the term, with those substances which are to have the honor of lodging within us. Hence the true name of the walking machine—

ORGANS OF RELATION.

And do you clearly understand the meaning of being in relation to substances?

Not exactly, perhaps.

When you wish to be put in relation to, or communication with any person, you apply to your friends, who furnish you with the individual's address, conduct you to him, or procure you an introduction. We have friends who render us the same service with the substances in question, and who are always ready at their post to put us in communication with them: these are the organs of relation.

The united working of these two sets of organs forms within us two very distinct kinds of life, each of which has received its distinctive name from learned men.

The first they have named Organic Life, which signifies life common to all beings possessing organs.

In the last chapter of "A Mouthful of Bread," which has for its title—"On the Nutrition of Plants,"—I have shown that a blade of grass nourishes itself as truly as man does, and what is more, by the same process, and thus far it possesses the same life that he does.

The other form of life which we have yet to study, and which has its seat in the organs of relation, has been called Animal Life, that is to say, life peculiar to animals. Those who have thus named it are perfectly sure that the smallest trace of this life cannot be found in vegetables; for imagine how absurd it would sound to say, the animal life of vegetables! As to myself, I never could feel so sure about this, and I must therefore in my correspondence with you reject these terms organic and animal life, which settle the question rather cavalierly; and I shall say, life of nutrition and life of relation,

thus naming them according to their nature, and leaving to the Almighty the secret of the limits of their domain. Before concluding this study, I shall endeavour to show that vegetables are not reduced to mere simple eating machines, that there is also among them a something which feels and moves, and that the difference in this respect is very small between them and what we call the lowest order of animals.

These two forms of life, that of nutrition and that of relation, I have already noticed, and I have marked out very clearly the ground where each manifests itself. I one day said to you,

"Your body is a little kingdom, of which you should be queen, but queen of the frontiers only. The arms, the legs, the lips, the eyelids, all the external parts, are your very humble servants ; at your slightest bidding they move or keep still ; your will is their law. But in the interior you are quite unknown. There, there is a little republic to itself, ruling itself independently of your orders, which it would laugh at, if you attempted to issue them."

We have travelled together through this little republic. It is now the turn of the little kingdom ; and if the first journey has been an interesting one, I sincerely hope this second one will not weary you. Queens have always found pleasure in travelling through their own kingdoms.

"Why then," you ask, "have you put this strange title, the 'Servants of the Stomach,' to your new task ? If all that we are going to search into has only been made to serve the stomach, of what am I queen, and how can I be proud of my royalty ?"

Alas ! my dear child, I am only a professor of physiology, as it is called. I have but one thing to teach

you, viz., how this little body, which you have in common with the animals, exists; and though I love you with all my heart, I can see in you during our lesson nothing but a little animal. The first duty, or, rather, let us say, the first necessity of the animal, is to satisfy this imperious master who nourishes the whole, but only on condition that the whole works for him. Yes, your subjects are his servants, because you yourself are his servant, and you rule for his benefit. What I say here is of the animal. Happy those upon whom it devolves to teach you the duties, to awaken you to a sense of the necessities of another life, of a life superior to that of the animal! These have the greatest, the easiest, and the most interesting task. They will teach you that all these organs which we are going to pass under review, were not given to you only to be servants of your stomach, and that, without quitting the great question of nourishment, your hands, for instance, were also made to give as well as to take it, your legs to carry it where it was wanting, as well as to carry you where the nourishment is to be found. We have, thank God, relations with other objects as well as with alimentary substances, and the organs whose duty it is to accomplish the acts of the life of relation do not confine their services entirely to the stomach. Some children might ask why these organs are called their servants, seeing that breakfast, luncheon, dinner, and supper follow one another regularly every day, without any apparent labor on the part of their organs. They are, let me remark, in passing, better able than others to employ these organs on something nobler, such as self-improvement, making themselves useful to their parents, in giving pleasure to one another, etc., etc. I must nevertheless assure you that the organs carry on their first duty though it may

not be their only one, even in a little child who does not appear to require them in order to enable it to eat.

These organs, we have already said, are appointed to put us in relation to the substances which we eat. Now, when you are seated at table, with a nice plate of fruit before you, which of the organs is intrusted to present it to you?

"There is only one," you reply, "and that is my hand, which carries the spoon to my mouth."

Indeed! is that the only one? What, then, of the eye which enables you to see the pretty color of the fruit, and the nose which tells you how good it smells, and the tongue, that dear little gate-keeper, what do you think of it—does he say nothing for himself? You have there at once three organs of relation quite as important as the hand; for each of them in its own fashion puts you in connexion with this precious substance called soup, without which little girls would never grow to be women.

But you understood that this work is only an amusement. With a child seated at table truly the business is more than half accomplished: what is placed before it only requires to be eaten. Some of these organs of relation can sleep at their ease, and those who watch do not require to fatigue themselves with the work. To see them all actively employed, let us picture to ourselves a wolf in the forest awaiting the hour of dinner.

The substances which are to form his repast are not all there within his reach, quite ready for his appetite. They ramble far off in the brushwood, under the skin of a goat or a deer, and it is no easy affair for him to put himself into useful relation to them. Now! see how the organs all work together in order to accomplish this difficult task. Look how many must engage in the

chase: the eyes on the watch, the ear erect, the nose to windward—three servants of his stomach who are on the look-out for him, and who report faithfully if they see, hear, or smell anything suitable. The prey thus tracked out by them, the next step is to obtain possession of it. For this purpose the bones, the muscles and the legs of the animal are called into action, fresh servants put suddenly in motion by a mysterious power which shows itself as by enchantment on the report of the scouts, and which has its seat in certain organs, the names of which you know quite well. There are the nerves, which must also be ranked among our band of servants, for without them the legs could no more move than could two pieces of wood. But this is not all. The power which the legs obey is a blind power requiring to be directed, and the indications of the eye, ear, and nose could not alone suffice for this, on account of the distance of the game and its own natural cunning, if there were not something more. What can it be? I should find it very difficult to tell you exactly what; at any rate, there is certainly a something which estimates the value of their indications, compares them with former indications of the same nature given in similar circumstances, decides what is to be done, and gives its orders accordingly. This something acts by means of an organ, so far as we can judge, and this organ is also a servant of the stomach. I am very sorry for the brain, for he it is, if this servitude should cause him to descend from the first rank. But if wolves could speak, they would tell us that with them the stomach is of more importance than the brain, and that the latter is only the principal, the head one, if you like, of all the other servants of the former. The whole of this army of servants sometimes work for hours, before the teeth

can take their turn, and what to you is the beginning of the task, is the end of it to the wolf.

Now, you can at a glance comprehend the full extent of the study we propose to undertake.

In order that the animal may be able to seek its food, it must be provided with an apparatus to carry it where that food is to be found, a regular machine, of which with us, the bones form the framework, and the muscles the cordage.

We shall, then, first study the bones and muscles, and I shall endeavour to make you understand the mechanism by means of which all the movements you execute are so easily effected, and that without your knowing how.

In order that this machine may act, it requires, like all those invented by human industry, a power to put it in motion. I do not promise to tell you exactly what this power is, because it is not perfectly understood; but I can show you the apparatus by means of which it is produced, and which is composed of nerves and brain.

After that, I shall take the scouts in their turn. These scouts are engaged in making discoveries, and are, in other words, the five senses. From thence we shall be obliged to make an excursion into what is called physical science, for how can we explain the eye without speaking of light, or the ear without speaking of sound? But do not complain, for these are very interesting subjects which it is well to know about at any age, and, therefore, much better to be known at once. The sense of touch will lead us to consider the skin, its principal seat, but which also fulfills many other functions, one of the most important being that of covering and protecting the whole body, as a paper cover protects the deli-

cate binding of a book. Lastly, we shall say a word about the intelligence dwelling in the brain; and here, my dear young friend, those who inquire the most profoundly into it are the most perplexed, therefore you must not ask me much upon this subject. I will tell you what is known, or at least what is presumed to be known, and for the remainder you will do as I do, you will wait.

This history of the servants of the stomach will be carried on like that of a "Mouthful of Bread." We shall first study these servants in man, where they are seen in full perfection, then in animals, where they are seen constantly retrograding and becoming effaced, in proportion as they are further removed from man, until they at last end, in some way, by all disappearing. Only this once, in order not to go again over the same ground, we will follow an order inverse of the former. Instead of commencing with those species nearest to man, and descending towards the lower animals, we shall take the latter as our starting-point, and thence we shall ascend to man, gathering up one by one on our journey all the relative organs he possesses, instead of leaving them by degrees on the road as we did with the organs of nutrition. In this manner you will better satisfy yourself that the animal machine is everywhere alike, and that the organs we meet with are always the same, only they are not always found in the same degree of perfection, and some of them may in certain animals be wanting. They may, in this state, be compared to the outline of a drawing; the strokes of the pencil are not all there, are not all finished, and in the first sketch it is often difficult to guess the subject of the composition, but a painter's eye will not be deceived by it.

Then, to conclude our research, we shall glance over

those traces of animal life that I pointed out to you a short time since as existing in vegetables, and by means of which they seem to fraternise with the lowest forms of animal life; forms which appear to us almost restricted to the narrow limits of vegetable life. I shall, however, have little to say on this subject, for it is a question that has not as yet been studied as it deserves to be, at least to my knowledge. I believe, nevertheless, that you will see enough to make you understand how modestly, how diffidently we should speak of nature, and how difficult it is to trace with certainty the divisions and subdivisions in this mysterious world of life, created by one fiat of the divine thought.

But this is a little beyond you, my young friend, and so here let me stop, for you have had enough for the present. Do not, however, run away from this lesson with the idea that whenever the stomach commands, you must obey. I have told you already, and cannot repeat it too often, it is only an animal which yields implicit obedience to its stomach. By reason, by conscience, by the power of the will, you are called to mount higher, and this is precisely the object proposed in the education of children, who would never make much progress if left to themselves. But this is your affair and not mine. I am examining a walking machine, primarily intended to work for an eating machine, and I need not concern myself with anything else. Let those who would be ashamed of being simply machines make their own reflections.

Still, let us understand ourselves. It is very well that the queen of this little kingdom should not always unthinkingly place her subjects at the disposal of her rival, the republic, and that she should know how to maintain her own authority when necessary. That, on the

other hand, it will not do to oppress this rival, nor refuse her what is just, merely for the pleasure of opposing her. She has also her rights, which cannot be infringed with impunity. To allow the life confided to her to languish, is to expose the higher life to languish also, for all our organs depend one on the other, and the stomach has a way of revenging itself on those who do not care for it properly ; it leaves the whole quietly to perish ; and the greatest sufferers are generally those who were formerly the greatest boasters.

It is but the old fable of La Fontaine's of the "belly and its members," of which what we have already said is only the explanation.

CHAPTER II.

THE BONES.

When I was a child I was always running, and as constantly falling down. I do not mention this as anything extraordinary; but I recollect that in those days a fall was of no consequence: no sooner was I on the ground than I got up again; the thought of breaking arms or legs never came into my head.

Now that I am a staid professor, a fall is a serious affair for me, and I do my best to avoid one when I run; nevertheless, two or three years ago, I do not remember upon what occasion, I found myself extended full length upon the ground, as in bygone days, and to my disgrace be it said, I had some difficulty in getting up again. I even think that involuntarily I put my hand to the spot that had received the shock, to ascertain that no injury had befallen me. I am then, as you see, already very far removed from my indian-rubber-ball condition, and if I should live to be an old man, the difference will be greater still. I must take care when I walk, for the risk of breaking a limb by falling would be considerable, and broken bones reunite less readily when one is old.

You also, my dear child, are accustomed to fall, and think nothing of it; but, believe me, such will not always be the case. I am no solitary exception; my history is but that of every other person.

But how is this difference between grown-up people

and children to be accounted for, as the bones of the former, from being more solid, would naturally break far less easily?

It is accounted for by the manner in which the bones grow in the body, and the changes they undergo in proportion as age advances.

You may often have seen meat-jelly, or, more properly speaking, bone-jelly, transparent and trembling upon a a dish. If you go to the cook whilst she is preparing it, you will see it is principally extracted from the bones of calves; thus, what cooks call jelly, scientific men call gelatine, and as gelatine is drawn from the bones, it is apparently because it is contained in them. In so great a degree does bone contain this gelatine, that the latter forms its basis, and the earthy substance, phosphate of lime, which by degrees hardens it into bone, is only, so to speak, a stranger who comes to lodge little by little within the flexible meshes of the gelatinous tissue.

You will, perhaps, hardly believe, upon looking at a ham or mutton bone, that any soft substance is contained within the bone. We have, however, a very easy method of ascertaining this, which I will explain to you; it will give you an idea of the way in which people set about discovering what is hidden within a variety of bodies.

A naughty woman once upon a time gave her little girl a cup filled with powdered sugar and marble dust mixed together, telling her she should have nothing to eat until she had separated all the marble dust without losing a grain, and without leaving any sugar among it. Many children in her place would have been puzzled how to act, and would probably have gone supperless to bed; but this little girl, who had plenty of common

sense, was not going to starve for such a trifle, so she emptied the contents of the cup into a large jug of water, when all the sugar melted, and the marble dust was soon left all alone at the bottom of the jug, not a grain of it missing, nor an atom of sugar remaining.

Those who discovered the means of separating the gelatine from its earthy companion were equally intelligent with the little girl. There is a liquid which has no effect upon gelatine, and in which the earthy substance with which it is filled, melts exactly as sugar does in water; this is called muriatic acid, a difficult name, but I cannot alter it. Allow the bone, which seems to you so hard, to soak for a certain time in some of this liquid. When you take it out it will be supple and flexible, will still retain its shape, but it will be reduced to a gelatinous tissue, retaining no trace of the earthy substance which had taken up its abode within its meshes.

Whilst the bone is in this state, try to break it by throwing it on the ground; you will never succeed, though it will bend, and even rebound like a piece of indian-rubber.

Well, then, in children the gelatine of the bones has not acquired its consistency, there are parts even where only gelatine is to be found; for instance, at the extremities of the arms and legs, which only become perfectly hard at about the age of twenty-one. This is about the period when persons cease to grow, because the work of growth, which takes place in the soft parts of the bones, ceases as soon as they become hard.

Let me give you an example that will prove the primitive softness of the bone in certain parts of the body. Place your hand gently upon the top of the head of a very young child as it lies in its nurse's arms; you will

feel the substance yield under the pressure of your finger, as if the bony arch of the skull was not complete, and in reality, at this period of existence, the different portions of which the skull is formed are only joined together by a species of gelatinous membrane, or, as it is termed by medical men, the fontanelle, or opening of the head; from this it results that the skull yields to the slightest pressure, and may be moulded with the hand to any form you wish. It is said, that the American savages take advantage of this softness of the skull to flatten their childrens' heads in infancy, according to the fashion of the tribe to which they belong. But it is a barbarous practice, from which the poor little creatures derive no benefit, for who ever gains by violently trying to alter the order established by Him who formed the human frame, and who knows what is best for each of His children?

To go back to our gelatine, you can understand that so long as it remains free in a portion of the bones, the latter preserve a certain degree of elasticity, and then is the time one can fall with the least chance of endangering a limb. Still do not trust to this, and be too rash, for should the fall be severe they will break even in children at their already hardened portions. If some heedless persons have the good fortune to escape, as your humble servant did, others are occasionally maimed for the rest of their lives, which is neither amusing to themselves nor their relations.

In proportion as a child progresses towards manhood, the earthy deposit is always increasing. It is about two-thirds of the weight of the bone in an adult, which, you must know, is a term applied to persons supposed to have attained their full growth. At this period, the bones being much less flexible will more readily snap. Later

in life, as old age comes on, the proportion of gelatine gradually diminishes, and the bones become exceedingly brittle. Thus you will understand how carefully elderly people should be saved from all risk of a fall, to say nothing of the respect and attention due to age.

I need scarcely tell you that gelatine is not found within the bone in the same form as that in which you are accustomed to see it on the table. If it were it could not have much strength or solidity. It is condensed in the bones in a compact, elastic, and resisting mass of shining, pearly white matter or substance, which is called cartilage. Take hold of the tip of your ear and the end of your nose, and you will feel what is called cartilage. The substance on the end of a knuckle of veal, which you sometimes crunch between your teeth, is also cartilage; and, to give you one more example, let me mention the bones of the skate, which may be crunched, and are all cartilaginous.

It is desirable you should know that the globules of blood (a history of which I have already given you at some length) do not enter within the cartilages. The blood penetrates into them, no doubt, seeing they are formed and kept up by it; but it is the serum only to which admission is granted, the globules being left at the entrance. Read over again the chapter on "The Composition of the Blood," if you do not clearly recollect what I mean by serum.*

Why this exclusion of the globules? I cannot tell you; for the canals which convey the serum are assuredly sufficiently large to allow the globules to enter. For information on this subject, I must refer you to one of my former lessons on the "Nutrition of the Organs," in which the history of the bones was only touched upon.

* See "A Mouthful of Bread," page 234.

I there told you how each of our organs has its own peculiar preferences, and takes from the blood only the portion suited to it; like dainty persons who select at dinner from the different dishes, and will not eat of all which come to table. It seems the cartilage belongs to this dainty class, and that the globules, so highly appreciated elsewhere, are not suited to its taste. This is the only reason I can give you.

The extremities of the bones which meet at your elbow—I only mention these, but the others have passed through the same stages—these extremities at the time of your birth were nothing but cartilage. By degrees these cartilages have strengthened; they have passed from a pearly clear white to a dull thick white; then they have taken a yellow tinge; at last, one fine day, a red spot suddenly appeared. This spot was formed by the globules of blood that had effected an entrance. At your present age, thoughts enter you head which you would not have listened to when you were younger. This is what has taken place in your elbow with the cartilages. Grown strong, they have listened to reason, and have opened a way to these energetic globules, which only asked permission to enter, in order to transform them into a state of bone, and to do the duty bone is expected to perform. The globules immediately set themselves to their work, and began to manufacture what appeared like a star, the rays issuing from which were of a stony nature, small in number and thin at first, but which, increasing and multiplying, finished at length by uniting and incrusting the end of the cartilage. This work, which is called the work of ossification, has been going on within you ever since, and the earthy deposit is constantly gaining upon the cartilage. When you perceive by your dresses that you have stopped growing,

you may take it for granted that the incrustation is complete, and the bone at the extremity firmly unites to that in the middle.

Let us now talk a little about this wonderful earthy substance, which the globules of blood manufacture so artistically. I told you, in its proper place, when speaking of the teeth, which are quite a distinct species of bone, that this was phosphate of lime; that is to say, phosphorus and lime, combined with a certain quantity of that same oxygen of which we spoke so much in reference to combustion.

I did not then tell you all I had to say. Phosphate of lime, it is true, forms the principal ingredient in the earthy portion of bone, but it is not the only element. Without wishing to fatigue you with a history of all its companions, the greater number being insignificant as regards quantity, there is one I must mention, because it is of some importance. It forms a sixth part of the ingredients entering into the formation of our bones, and we shall meet with it again by and by, occupying a most important position in shells, which are the bones of shell-fish, bones which are to be found outside instead of inside the animal; that is the sole difference. This is carbonate of lime, the result of the marriage between our old friends carbonic acid and lime.

And can you tell me of what the Paris houses are built? They are built of this very carbonate of lime which the globules of blood manufacture in your arms and legs, and, what is more, of carbonate of lime which is manufactured almost in the same way. It is derived, in a great measure, from an innumerable host of imperceptible animals, each one of which constructed a shell, which, in dying, he left behind him. All this took place long, long ago, much longer than you can imagine; and it is from the mass of these shells, hardened by time, that

the rubblestone of which almost all the Paris houses are built has been hewn. You thus see that our internal manufacture of stony material is not peculiar to man; but that this same manufacture has been widely spread over the earth ever since life had its beginning there.

The phosphate of lime, the carbonate of lime, and the other earthy ingredients glide so easily through the thickness of the primitive cartilage, as in some degree to form a new bone enclosed in the first, and which in its turn can be separated by a far more simple process than by the use of muriatic acid.

No great amount of science is required to discover this, and you can try the experiment any moment if you like. All you have to do is to throw the bone into the fire. The gelatine burns and is no more seen, the earthy portion only remains. Weigh the bone before you burn it, and afterwards, you will at once perceive that something of the weight has been lost in the burning. In other respects, its appearance will be unchanged; only the bone will be drier, more porous, and more brittle. This will easily be understood, because the organic substance which surrounds the bone, with its flexible and resisting arms, has been consumed by the fire.

If, then, we have within us, in the heart, as I once told you, a sort of vegetable, a kind of animated tree which sends its roots to the intestines in search of sap, and its branches to the lungs in search of air, we have in the bones, a mixture of several minerals where organic and inorganic, or dead and living substances, struggle for the mastery from the beginning to the end of life. Man is not simply the king of creation: he is an epitome of it, and little girls are far more interested than they imagine in becoming acquainted with everything existing in the lower ranges of creation, for it is all to be found in their own bodies.

CHAPTER III.

LIFE OF THE BONES.

These stony portions of our flesh, these living stones form in the midst of our organs a world of their own, remaining in some degree strangers to all the agitations, the tremors, and the movements of general life. There is great sympathy between the different parts of the body; all languish or prosper simultaneously. Our organs are a society of true friends, who grieve or rejoice together. The bones alone remain passive, while all else is in commotion around them; they are like unfortunate children, with hearts of stone, who never trouble themselves about anything that happens to their companions.

You remember the day when you cut your finger so severely, of which wound you still bear the scar. Your whole dear little body suffered with your poor finger. Your lungs and throat uttered so loud a cry that your mother came running from the far end of the garden, whilst your cheeks became very red, and scalding tears rolled down over them. Your legs gave way, your arms trembled, and if any one could have put his hand to your heart he would have felt it beating far more violently than usual; and as you had just dined, your stomach, which was quietly carrying on its duties, became disturbed to such an extent that its work was interrupted, and you had, if I remember rightly, a slight attack of indigestion.

What part did the bones take in this general agitation?

None whatever ; they allowed themselves to be tossed about right and left by the convulsed muscles, but personally they did not suffer the smallest emotion. You would know nothing of all this, being absorbed in your little accident. Try and take notice the next time you cut yourself, it may divert your attention ; and who knows whether thinking of the calmness of these unheeding bones will not help to moderate the excess of agitation in the rest of your body.

It would seem, at first sight, that the bones are equally insensible to their own misfortunes as to the misfortunes which overtake the other parts of the body. In those dreadful operations, when to save life a member has to be sacrificed, whilst the whole body painfully shrinks from the surgeon's knife, the bone may be sawn with impunity, so to speak, for at this moment the pain is almost null, but this privilege of insensibility is but apparent. I think it was Jean-Jacques Rousseau who appeared to such disadvantage in *viva voce* discussions, and only discovered an hour after how he ought to have replied. This in no way detracted from his eloquence when he answered with his mind in repose and his pen in his hand. It is the same in the history of the bone ; it is dumb whilst the saw is at work, but vexes itself when all is over, inflames, and then becomes formidably eloquent ; you must, however, give it time to inflame, and this is not the affair of an hour. The extreme slowness of its actions is the characteristic of the life of the bone ; there the dead crowd so closely to the living that the latter is benumbed, and sleeps as if in a tomb. This is the reason why the bones look with indifference on the general excitement when any sudden accident befalls the body ; all is right again before the troubles of their neighbors have had time to arouse them. But in chronic

cases, or illness of long duration, if you prefer the term, the bones sometimes end by partaking of the general disturbance, they suffer in their turn, and become the scene of frightful pain, against which all medical skill too often proves powerless.

One circumstance infallibly rouses the dormant life of the bones, and this is a case of fracture.

The day you cut yourself, if, instead of crying so much, you had spent your time in looking to see how things were going on, you would have observed that as the bleeding ceased, a kind of yellow gluey liquid oozed from the lips of the wound, and as it dried up soon indurated them. By degrees the little vessels which had been cut in two, hollowed out a way across this thin pellicle, and rejoined their walls. Like a good workman who sets to work to repair his work after an accident, the blood connected the divided fibres, carrying away by degrees the coating which temporarily held them, and now if you have the curiosity to examine further by cutting your finger again in the old place, you would satisfy yourself that no trace of all this repair remains inside.

The bones repair their injuries in the same way. When they break, the little vessels which run here and there in their interior also break, and the blood flows as when you cut your flesh, but, of course, not to the same degree. Soon a yellow coating, like that which healed your finger appears, but what would suffice for a little bit of flesh would be too weak for a heavy massive personage like a bone, therefore the whole history of ossification must recommence in the broken part. The gelatine comes first in order, then little by little a cartilage is formed by the exclusive intervention of the serum ; next, the globules work in their turn and construct a bony

wall, which exactly fills the breach, and at last permits the bone to work as before.

How long a time did the cut in your finger take to unite? Some hours, a day at the most; wounds of this kind heal quickly at your age. With bones there is so much more work to do that more time is required, and their progress is very slow. For a man in good health it takes from two to three months before the cure is completed, but there is no exact limit to the time necessary, the vitality of the bones being proportioned to the animal substance they contain; in elderly people, where the gelatine has in a great measure given place to the earthy substance, much more time is required for the healing process. We read of fractures coinciding with certain maladies, which have required six or eight months to consolidate. Vitiated or enfeebled blood is like a workman out of health, who works without energy, and is always behind.

On the other hand, in children whose blood is so active, and whose bones are half gelatinous, fractures sometimes heal in a marvelously short time. I know an instance of a little boy, who for fun climbed a neighbor's fence. Surprised in the act, he jumped without looking, entangled his leg in a cross-bar, and broke it. Before a month had elapsed he was out limping along the road: this was certainly too soon; under similar circumstances your parents would have kept you in the house much longer, for a bone imperfectly united and used too soon will easily break again, or take a wrong direction, and the second injury is more difficult to repair than the first.

You perhaps have seen a broken limb; if so, you will understand why they bandage it between splints of wood so as to prevent all movement. The slightest motion

displacing the two pieces of bone laid together would derange the whole operation, which would require to be recommenced, and if too often repeated the bone would not unite at all. The blood becomes discouraged if its work is too often undone ; it is no longer found equally capable of action, and at length leaves its work half finished ; in this case it unites the two broken ends in a clumsy manner, joining them by means of a species of fibre, as a driver repairs his shaft, which has been broken on the road, with cords, and the limb has to move along as best it can.

Do not forget all this if you meet with an accident. Take care not to stir your foot, if it is your leg that is broken, nor your hand if it is your arm, they might either of them in the movement displace or draw aside the portion of the bone next to them ; and do you know what would happen if the two broken extremities were to separate from each other? The uniting ligature would be pushed to one side, and the globules arriving, would ossify it, and at last one leg would be found shorter than the other. It is very tiresome for a little girl to remain for several weeks upon the sofa, but it would be still more trying for a young lady, when asked to dance, always to rise with a limp, and be obliged to admit that it is her own fault that she does so.

The repair accomplished by the blood when its previous work has been damaged or destroyed will appear quite simple, if you recollect what I told you of its twofold duties as constructor and demolisher. It incessantly destroys our bones, and as incessantly renews them, so we ought not to be at all puzzled when any addition is required—this is a game it is quite accustomed to. What would you say if I were to tell you the way in which these demolitions and these reconstructions are

continually carried on? You would open your large eyes, and think I was making fun of you. It does not appear very easy to ascertain what takes place in the depths of your bones, where the eye, if it could penetrate, would see nothing. Nevertheless, we know what goes on most positively. Listen, then, for it is a history which is worth the trouble of hearing.

You must first call to your recollection what I told you last time about the gelatine and globules; about the different appetites of our organs, one of which takes this, and the other that out of the blood. It is owing to this mysterious instinct that each one is fitted for performing its allotted task, and if we consider this properly we shall find it could not be otherwise, our body would be only a uniform block without this intelligent distribution of the materials of which it is composed. But there is something besides this. Independently of those wants which it is requisite to satisfy, the organs have their fancies as pretty little girls have. Among the multitude of substances which may find their way into the body under one pretext or another, there are some which are seized upon by one organ only, even though they should not be necessary to it; even though they may be injurious to it. In this again they resemble little girls. To bring forward a very inoffensive example. The madder with which the cloth for soldiers' uniforms is dyed red, owes this honor to what dyers call a coloring principle, which is spread throughout all parts of the plant, so if an animal eats madder, this coloring principle which enters into the body, and which the other organs do not like—the bones have the coquetry to absorb on its passage to give them a fine red color. Where, I ask, will coquetry end? We are indebted to it for this secret.

An experiment was made by feeding some pigeons on madder, and afterwards killing them to see the effect produced. In those fed for some time on this diet, the bones were quite red ; in those birds which had been fed thus for several days, the surface only of the bones was red ; when madder and the usual food had been employed alternately every fortnight, alternate layers of red and white were found upon sawing the bone, corresponding to the different periods ; lastly, in birds fed upon madder for a certain time and then restored to their customary food, the bones were quite white, the redness having departed, though traces of it were discernible upon a close examination of the heart of the bones, for the old layers disappear from the centre in proportion as new ones deposit themselves on the surface.

Our bony framework, then, follows very nearly the same laws in its formation as does the ligneous portion of vegetables, the solid part of which also increases by the deposit of superficial layers advancing regularly towards the interior or from without inwards, in consequence of the accumulation of the successive layers which are continually being formed. There is this difference, however ; in the bone which belongs to a superior order of existence we remark two kinds of movement, one implying ingress the other egress, while the life of wood, more simple in its nature, is satisfied with the accumulation of new layers on its surface without interfering with the old ones, which death only destroys. On the other hand, I can show you another very curious point of resemblance between bone and wood.

I have already told you that wood is produced year by year by the bark of the tree. The bone also has its bark which produces it, but without intermission, as in this hot-house of ours, always heated to 98° Fahrenheit,

winter is quite unknown. It is a membrane surrounding the bone called the periosteum, a Greek word, but easy to remember, meaning "around the bone."

All the small arteries of the surrounding parts send their last ramifications into the periosteum, which last becomes swollen by the blood, as the bark is swollen with sap, and both work exactly on the same plan.

If I had entered more particularly into the history of the formation of wood, I should have told you that a sort of preparatory wood is formed between the bark and the ligneous portion called sapwood, which, after remaining white and soft for a certain time, becomes hard wood, as it is called.

What is directly formed from the periosteum is really like sapwood in its nature.

What is a cartilage? You know now, it is a bone in process of formation. Now in the first half of human life, a thin layer of cartilage is formed under the periosteum, the interior of which gradually ossifies, and which is always being reproduced at the exterior surface until the growth of the bone is completed. Later on, the periosteum itself ossifies in its turn, so much so, that in the end it is almost impossible to separate it from the bone with which it seems to identify itself, its work of construction languishes, and by degrees ceases, and owing to the interior destruction always continuing, the bones of old people gradually become thinner, and this is another cause of their fragility.

You see now, that I had some reason for naming this chapter "The Life of the Bones," though probably at first it astonished you. Remember I have not told you all that is known, and we are far from knowing all that may be learned on the subject. In looking at one of the little bone figures you see in shops, would you believe

the story of its having lived, of its having issued drop by drop, that is the term, from a membrane which is sometimes thinner than a sheet of paper, and that had the animal lived long enough, the bone which it represents would have disappeared little by little in the blood! How many things which closely concern us we are ignorant of, and if we have already found so many curious particulars to learn respecting the lowest of our organs, those in fact which but half live, what will it be when we come to examine those which are in some degree the seat of life?

CHAPTER IV.

THE MARROW.

Let me now introduce you to an intimate friend of the bones, I mean the marrow, which, if not forming a part of, dwells within the house, which you know very well by name.

The marrow is a species of oily fat, finer and more easily melted than that of the rest of the body, and is found in the interior of all the bones. I must here say a word as to their construction.

Examined through a microscope, the bones seem composed of a multitude of fibres everywhere the same, which are sometimes pressed one against another, forming what is termed compact tissue, a name which explains itself, and sometimes crossing one another in every direction, forming a lighter kind of tissue, called cellular tissue. There is a system in prison called the cellular system, because the poor culprits are shut up in separate cells, in the hope, it is said, of softening their natures, provided they do not die, or become insane. In like manner, the cellular tissue owes its name to the empty spaces between the crossings of the fibres, which form so many little cells, through which the canals containing the blood circulate. These two kinds of tissues are found in all bones,—the compact at the exterior, the cellular in the interior, but in different proportions. In the bones of the skull, for instance, which belong to the class of flat bones, the two exterior plates of compact tissue are in such close

contiguity, especially in old age, that it is sometimes difficult to find traces of the cellular tissue. The latter, on the contrary, predominates in the short bones, such as the wrist and instep, where the compact layer is very thin, and only looks like the covering to a mass of cells of which the bone is composed. Lastly, in the long bones of the arm and leg, the separation of the fibres at the two extremities there determines the cellular swellings organised like the short bones, whilst the middle forms a species of tube, the sides of which are composed solely of a compact tissue, thicker even than that in the flat bones.

Excuse, my dear child, this dissertation upon flat bones, long bones, compact tissue, and cellular tissue. There are so many things to search into in this little country we are exploring, that to derive benefit we must tread in the steps of those who have seriously studied them, and all who desire to gain knowledge must accustom themselves to search diligently into what is not always amusing.

To come back to our subject, the marrow, it is to be found everywhere, whether in long, short, or flat bones; in all tissue, whether compact or cellular; it is the inseparable companion of the bony substance in its minutest structure. It is even found in the teeth. If you wish to be convinced of this, examine one of those old pieces of ivory you find in curiosity shops. Do you know why they are so yellow? Simply because the oil, that is to say, the marrow, which is contained within them has become rancid from exposure to the air, and turned yellow, though it was colorless before. Pass your fingers over a piece of polished ivory; it is the marrow it contains which renders it so soft and unctuous to the touch. I once told you, that teeth prepared by the dentist from the tusk of the hippopotamus soon turned yellow in the

mouth, now you will understand why. The hippopotamus, like all aquatic animals, is rich in oil. You take no thought as to what may happen to those little white pearls which look so pretty when you laugh; well, supposing one of them was to fall out now, and you kept it, it would grow old as you do, and by the time you become a grandmother, would be quite yellow.

If the marrow succeeds in establishing itself in the tissue of the teeth, which is by far the most compact of all the tissues, how much more easily will it find its way into the others, which for this reason also become yellow much more rapidly than the teeth do. Take a bone of a sheep with a pair of tongs, and hold it over a fire, presenting the middle, which is so hard, to the flame, the heat will liquefy the marrow, and it will ooze through the imperceptible holes with which the surface is riddled, and falling in drops on the fire will burn with a bluish flame; if you let the marrow drop into the fire from the thick end of the bone, which is all cellular, it will make a stronger and brighter flame, and will continue burning like a torch after you withdraw the bone from the fire, until all the marrow is consumed.

The real habitation of the marrow is in the long bones, the hollows of which are filled by long rolls of it; elsewhere it is scarcely discernible, lost, as it is, in the depths of the bony tissue, whereas in the long bones it dwells apart, and may easily be seen.

The long bones have a small opening near the centre; look for the hole the next time you have the leg of a chicken on your plate; it is called the nutrient orifice, because it forms a passage through which a large artery feeds the captive immured within this stony cylinder.

Scarcely does the artery enter the prison of the marrow, when it suddenly divides, forming two branches,

each accompanied by its vein, the one running upward, the other downward. Arteries and veins forming innumerable ramifications envelop the marrow in so tight a network that it acquires a red tinge in consequence, more especially in young animals, in which nutrition, and consequently the circulatiou of the blood, is more active. Thus, well warmed, well fed, and sheltered from all accident, the marrow lives within its walls, like a mouse in a cheese, regardless of what takes place in the body, and doing nothing, at least so far as we can see, though doubtless it has some kind of work to do, and we could not with impunity suppress this lazy marrow, which seems to have no employment.*

A great fright seems, however, to affect it. Have you never heard the expression, "It froze the very marrow in my bones?" Terror stops the circulation of the blood, and accounts for this feeling. The work of the nutriment-admitting orifice, or the opening by which the

* An ingenious savant conceived an experiment—they call it an experiment!—the details of which I will not give you, for I do not wish to set your hair on end,—in which the marrow is suddenly destroyed in the interior of a bone, of a dog or a cat it is true; the love of science has not yet led to the trial of such experiments on men, and this is fortunate. At the moment of the experiment the bone dies, but a very singular phenomenon takes place afterward. The periosteum becomes inflamed, swells, separates itself, as it were, from the dead substance beneath it, with which it has no longer anything to do, and begins boldly to fabricate a new bone, in which the dead one is enclosed.

This is a beautiful illustration of the power of the periosteum in the production of bone, and it enables us to understand those surgical operations recently conceived, in which the destruction of a part of a bone is remedied, by carefully replacing the strip of periosteum which covered the piece of bone which is removed. This strip of periosteum fills up the vacant space which exists beneath it, and a perfect bone is ultimately the result.

nutriment is furnished, is interrupted, and a trembling of the marrow is natural.

This reminds me of a popular saying, applicable to people who are wanting in energy, "He has no marrow in his bones." By what instinct do those not versed in anatomy arrive at this conclusion? they are in some measure right. In delicate and rickety persons the marrow loses its fat, its virtue, and is replaced by a gelatinous liquid, sometimes forming three-fourths of the whole original quantity of marrow. Little children, whose energy is not very great, have not much marrow either, and what they have is but half formed, the gelatine and the fat being about equal.

I trust, however, you will not lay too great stress upon the popular respect for the marrow; like all respect which is not enlightened, it borders upon superstition. For old people who are feeble have more marrow than younger ones; the mass increases in proportion as the space which it has to fill widens, in consequence of the thinning of the bone in the interior.

The Greeks held the marrow in great respect. It is said that the centaur Chiron, the preceptor of Achilles, fed his pupil upon the marrow of the lion to make him brave. This is a receipt I should not feel inclined to recommend, even supposing we could acquire the properties of the food we eat, which would often be very disquieting. Even in lions the marrow has nothing heroic.

But we have said sufficient about this fat inhabitant of the bones; let us pass on to a subject which is also of great importance—the manner in which the bones are attached to each other.

CHAPTER V.

THE JOINTS.

Had your arm and forearm been of one piece, and had the two parts of your leg formed but one, you would not have found them very convenient; had they been firmly fixed to the body as the branches of a tree are fixed to the trunk, it would have been still worse; your powers of mobility would scarcely have exceeded those of a statue, and your head would have been of little use if unable to move on your shoulders.

It has been wisely arranged otherwise. Our bony framework is composed of movable pieces, harmonising one with the other in such perfection, that no machine invented by man can be compared to it.

At the present day we have machines everywhere, and I am sure you must have seen one at work, though it may have been only a sewing machine. What a noise! what shaking! what constant friction goes on among the different pieces of the machine as it performs its duty; and what a trifle will put the whole into disorder, at the very moment when it appears to be working rapidly and perfectly.

Now place yourself by the side of this noisy assistant, this sewing machine which your mother has bought, in order to accomplish the extra sewing you cause her; and while it is in movement, do you, without saying anything, just move your arms and legs. There are, in these also, different pieces which rub one against the other;

but do you hear the least noise, do you observe the slightest friction? These pieces have neither screws nor nails to keep each one in its proper place, and those which do the most work scarcely meet, as we may say, at the extremities. You must own that these members require to be fastened firmly together, to overcome all the obstacles they encounter.

The points where the fastenings are found are called joints or articulations.

There are two kinds of joints, movable and immovable, and, without going any further for an example, I can explain them to you by means of knives. Knives are also jointed; they are composed of two parts, the handle and the blade. In pocket-knives, which open and shut, the position of the blade is changed at will by turning it upon a pivot at one end of the handle, this is a movable joint. In table knives, which always remain open, the blade is fixed in the handle, this is an immovable joint.

The skull bones belong to this latter class.

The different pieces of the skull, as they lean against each other, form a kind of circular arch, behind which the most delicate of our organs is sheltered, that one requiring the greatest protection, viz., the brain. Think what would become of an arch if the stones composing it were movable, and you will see that movement in the bones of the head is out of the question. One thing is absolutely necessary, the solidity of the whole; and when we consider the thinness and the small extent of surface where they meet, we should be tempted at first sight to ask with some uneasiness, how bones so delicately formed could manage to avoid overlapping each other upon the smallest pressure; when we examine the joints we are soon reassured. They are scalloped by a number of minute zig-zag indentures, which fit into those on the

corresponding edge, like the serrated teeth of a cog-wheel, and dovetail so one with the other, that unless told beforehand, you would never imagine the skull was formed of more than one bone. Now, in virtue of the constant progress of ossification, these several bones end really in becoming but one, for all these zig-zag indentures finish by becoming solidly attached as age advances; and the absolute immobility of the articulations, even when the bones only touch, does not permit of our perceiving the change when they really become united.

The movable joints, such as those in your arms and legs, are quite differently constructed.

Place two bits of wood end to end, and glue a piece of linen loosely round the extremities, and you will have some idea of the way your bones are fastened together.

Only the linen is as cobweb in solidity, compared with the materials nature uses. I cannot show you those at your elbow, your shoulder, your knee, etc. I sincerely hope you may never see them; still there are some exactly like them which you must have already seen.

In cutting up a fowl, the famous joint, the speedy discovery of which is the triumph of the skilful carver, is simply the articulation of the wing or of the leg, and the kind of skin of pearly white which adheres to the extremity of the bone, and which so vigorously resists any effort made to cut or tear it, is the material or membrane in question. You can easily test its strength the first opportunity you have, and I wish you luck with it, above all, should the fowl be an old one.

Science calls this covering of the joint the fibrous capsule; it is a small closed sack, inside which the extremities of the two bones have full play, without being able to pass certain limits; they are not retained within their allotted space exclusively by the resistance of the fibrous

capsule, and on this point I shall have more than one peculiarity to notice when we shall be speaking of the bones separately; nevertheless, this power to retain the bones in their places is the special function of the fibrous capsule, and you may here admire the wonderful intelligence adapting each member to the performance of its destined duty. The fibrous capsule may be cut, may be attacked by substances, which, if applied to other parts of the body, would give rise to great pain, without evincing the slightest inconvenience. It sends no complaint to the brain, where resides the authority charged with the care of all parts of the frame; in other words, the fibrous capsule knows no suffering; but only pull the limb, twist it, and bring about, no matter how, a separation between the ends of the bones, and immediately the brain is advertised by this same capsule, which instantly becomes the seat of intense pain. Like a stolid sentinel, it only knows its own password; all beyond this is nothing to it.

Let me remark, however, that this pain inflicted upon the fibrous capsules, which retain the extremities of bones in their places when the limbs are pulled or twisted, is not the same at all ages.

These membranes are much more supple in children, and sometimes, when violently strained, stretch to an extent which would be impossible at a later period of life, unless by violence oft-repeated we force them to take a particular bend, which they ever afterwards retain, in defiance of the laws imposed on them by nature. It is owing to the suppleness of the fibrous capsule in youth that mountebanks are able to exhibit themselves in postures which would completely turn the heads of those who might attempt to imitate them. There is but one age for an apprenticeship to this calling, and that is early

youth; and posterity will bleed for us when they shall read, in history, that we have tolerated such cruel practices to be inflicted on helpless children, practices which public opinion ought to have suppressed long ago.

These fibres, which, unfortunately for the poor children, are so flexible at first, are not long in stiffening, and would positively refuse, if not acted on at the right time, to yield to these exaggerated displacements which may be obtained of them in early youth. As we get older the joints acquire strength, they gain in solidity what they lose in flexibility; they have less play, but they work better.

In old age the texture of the capsular membrane becomes extremely rigid, and often incrusted with phosphate of lime, which causes old people to move about slowly, and often with difficulty, feeling it painful to stoop to pick up anything from the ground. Happily there are generally children at hand with supple fibres, who are glad to stoop for them.

Up to the present moment we have only noticed the exterior of the joints; we must now look into the little sack, and as I cannot do this in your leg, once more turn to the leg of the chicken.

Examine the point where it is detached from the bird very carefully, and you will find the extremity covered with a white surface, elastic, beautifully polished, rounded in the form of a ball; you will further see that this ball fits into a cavity in the corresponding bone; now separate the joint uniting the foot to the leg, you will see on the two articular surfaces, ridges and grooves as if made by a lathe, which are adapted to each other with unequalled precision. You have but to pass your finger over this admirable piece of work, to understand at once how the different pieces of the animal machine glide, or

work, so easily and with so little noise, the one on the other.

These bones are terminated by cartilages, but they must not be mistaken for the cartilage found in children, of which we have already spoken. The cartilages of the joints are common to all ages, and form an essential part of the articular system. Their principal office is to deaden by their elasticity any shock, and thus they prevent many fractures, as is the case in machinery where indian-rubber bands, buffers as they are called, are placed over the metallic parts at the points of contact. Add to this, that the bone itself could never take on this incomparable polish which is due to the extreme fineness of the cartilaginous tissue, the meshes of which are so very close as to be almost imperceptible. If by chance the articular cartilage were destroyed, the two bony surfaces would, it is true, acquire a certain polish from constant friction against each other. Instances of this kind are recorded, but I doubt if the members would willingly accommodate themselves to this substitute, and the facility of the movement must assuredly be affected by it.

There is yet another contrivance which probably you do not suspect.

We grease our machines to facilitate their working. From our watch-wheels to our door-hinges, each joint receives its proper quantity of oil, destined to make it play freely. Nature has not neglected a proceeding which we find so essential.

Under the fibrous capsule, another membrane is found, arranged in form like a purse, within which the joint is enclosed, and which incessantly distils a slimy liquid called synovia, a funny word to write, but quite as easy as many a child's name to pronounce.

Have you noticed, when travelling by rail, what took

place when you stopped at the principal stations? Did you observe men, with pots of grease in their hand, running from one wheel to another, opening successively the boxes which enclose the extremities of the axles? These are called journal-boxes, and they must be looked into from time to time to see whether the provision of grease requires renewing. The purse which distils the synovia is also a journal-box, but a far more perfect one than those attached to the railway-cars, inasmuch as it is self-replenishing and does not require any thought from us. Stop a moment though! I am mistaken; it is our duty to assist the action of this membrane, but I may truly say the assistance required is not onerous; it consists in moving your limbs from time to time. However small the aid you render, you will see that to deny it altogether would entail suffering.

Have you ever been a long time without eating, speaking, or laughing, without moving your jaws in any way? If this has never happened to you, no doubt but it will some day. In such a case your mouth becomes perfectly dry after a time, as if there were no saliva left, and in fact the supply is wanting; for the salivary glands require encouraging to do their duty by being constantly exercised, they sleep if left to themselves, and the mouth, which the saliva should keep constantly moistened, becomes dry.

The same thing takes place in the synovial membrane; the discomfort you experience when you first begin to move your limbs after they have been sometime in the same position, all proceeds from a similar cause, the journal-box is dried up, or rather the grease has become thickened for want of being renewed—it clogs, so to speak, the articulation. When the synovia dries up, it is a terrible affair; the consequence of this is more serious than you can im-

agine. The two cartilages, the contact of which nothing has any further power to soften, slowly inflame, swell, and adhere together ; instead of being movable, the joint is no longer of any use. Do not be alarmed and think it dangerous to sit quietly during your lessons. A day, or even a month could not produce such a sad state ; such transitions require time ; the bone works slowly, as I said before. To produce this change, a long illness or a stubborn fracture, keeping you close prisoner to your bed for an indefinite period, is required ; you rise with an ankylose, or stiff joint, for this is the literal meaning of this terrible word, it comes from the Greek ankyle, which signifies joint.

In all this, dear child, I see an interesting lesson, valuable as it is interesting, if you will only profit by it. Your membranes and glands are not the only parts of your body which sleep if they are not exercised. The same law holds good with your whole being, and our most valuable faculties also sleep if we do not take pains to keep them well employed. Doctors, in cases of prolonged immobility, with a view to prevent this serious result, where it can be done, make their patients perform all sorts of apparently useless movements.

I wish that, in accordance with this example, young people would only feel uneasy whenever the opportunity for doing good does not present itself frequently enough, and that they would rather seek such opportunities than allow their kind-heartedness and intelligence to rust. Ankylose of the heart or the mind is far worse than that of the arm or the leg. One word more on the synovial membrane, and we will take our leave of the joints.

It is not very strong ; it is one of the serous tribe of membranes, so called because they distil a liquid which they draw from the serum of the blood, they look some-

what like a piece of wet bladder; well, slight looking as this membrane is, it proves when necessary as good a keeper of order in the joint as the robust capsule with its indomitable fibres.

This serous membrane and the soft synovia are so closely applied to the articular surfaces that they let nothing enter, and the articular surfaces cannot quit each other without creating a vacuum, and you know what a strong antagonist you have to deal with if you wish to produce a void anywhere. I gave you an insight into atmospheric pressure when I spoke to you about the lungs. The full pressure of the air is behind this feeble membrane, and opposes any displacement of the bones, which are thus rigorously kept in position even after the fibrous capsule has been removed. In such a case the most violent effort will not always separate the joint. Make the slightest cut into the synovial purse, and allow the air to penetrate the joint which it protects, and the powerful auxiliary is neutralised, and the object is accomplished with the greatest ease.

You, my dear child, are not very strong, and probably never may be. Let this teach you what energetic resistance the feeble may oppose to brute force when the former have on their side reason, justice, right, all those great forces of the moral atmosphere, the irresistible pressure of which is everywhere obeyed, always provided their natural and legitimate action be not broken in upon.

CHAPTER VI.

THE VERTEBRAL COLUMN.

Hitherto we have only occupied ourselves with what is common to all bones; or general anatomy, as it is called. Now we pass on to a description of the bones taken separately—descriptive anatomy, as it is called—and you cannot imagine how many pages might be filled if I should attempt to lay before you all that could be said of them. The body of a man is certainly not very large, and yet those who would seriously study it must spend years at it to know even a little about it. So many, so various are the details in this admirable machine, of which each atom is worthy of attention, that a lifetime would not suffice to discover all that is to be learned. Still, as we have no desire to become physicians, we will proceed more rapidly. It is a little satisfaction to get a general idea of a subject of which we knew nothing before.

Let us begin with the vertebral column; it is the foundation of the structure, and to it all the other parts are attached; and you will understand when we come to the history of animals, why I give it the post of honor. You already know, moreover, that this column has given its name to the whole class of vertebrate animals, beginning with fish, and ending with man. The most important and marked distinction which can be established in the animal kingdom is that of vertebrate or invertebrate animals; that is to say, they all belong to the one or the other, according as they have or have not a vertebral

column. In classifying animals I should seek another distinction, for, in being more minute, one runs a risk of getting confused and bewildered.

The vertebral column is situated on the median line of the body.

This expression seems to astonish you, but do not be alarmed, I shall take care before going further to explain this important median line to you.

Place your finger exactly in the centre of your forehead, run it straight along the bridge of your nose to the bottom of your chin, whilst you look at yourself in the glass. You will at once see that each side of your face, right and left of the line, is exactly like the other. To the right there is an eye, with eyebrow and eyelid, to the left there is the same; on each side there is a cheek, beyond that an ear; your line separates the nose into two equal parts, and a glance will satisfy you that each is a counterpart of the other; it is the same with the mouth. Now take notice of the little hollow just below the nose, in the centre of the upper lip; you will find the same number of teeth on either side, incisors, canine, and molars, all placed in the same order as if the two parts of the jaw were two distinct jaws, united so as to form but one.

This is no simple supposition. Nothing is easier than to perceive traces of this junction, especially in the lower jaw, where it is indicated by a kind of ridge. We sometimes see children with what is called a hare lip, that is to say, with a cleft in the centre of the upper lip, which, in certain cases, extends far into the palate; if it could possibly extend farther without causing death, and a curious eye could pursue its track, it would, in passing between the two uniform parts, reach the top of the skull, which at the centre bears the mark of a large

weld, dividing the skull into two parts, of which one is but a repetition of the other.

Let us continue this imaginary division throughout the trunk down the middle of the neck, each half will have an arm and a leg like its twin, the same number of ribs, the same quantity of muscles and nerves all placed respectively at the same points. The conclusion to be inferred is, that a line of separation traverses the whole body, forming, if I may so say, a limit between two distinct individuals reunited by this median line.*

Thus the vertebral column is situated on the median line of the body, and I need not again tell you that, like the nose, jaw, and skull, like everything which is on this line, it presents on either side, throughout its entire length, two surfaces precisely alike; its construction is not the less complicated in consequence, and requires to be explained in due order.

The great bone found in the centre of a fish is simply its vertebral column, and it may give you some idea, faint though it be, of your own. You know how easily it can be broken into little rings, as it were, pierced

* It is only the organs of nutrition which escape the law of equal and symmetrical division, the heart being on one side, the liver on the other; the intestinal tube is rolled up on itself, and yet this irregularity of division is more apparent than real. It arises chiefly from the fact, that the intestines are rolled up like a package in the cavities which they fill, and if we stretch out the intestinal tube and divide it lengthwise, its name alone (tube) tells us that we shall find in it two halves resembling each other perfectly. The heart, the lungs, and the liver are double also, with certain inequalities, it is true, as regards the dimensions of their parts. The arteries and veins are pretty equally divided between the two halves of the body, so that, with only a few exceptions, the organs of nutrition seem to have been constructed on the same plan as the organs of relation, and to be formed, like these latter, of two organs resembling each other, united at the middle.

with two large holes, one above, the other below. On dividing these bones you will perceive at the entrance of the hole, a kind of fatty pulp passing from one bone to the other, and serving to unite them.* Each piece is surmounted by a triangular ring hollowed out at the base of a long straight sharp bone; these rings, which follow in succession one above the other, form a canal through which a whitish thread runs; trace it to the head where it ends, and you will there observe a ganglion of light lines, which is neither more nor less than the brain of the fish. Do not be angry, for a fish has a brain as well as you.

This is quite a course of anatomy, is it not? but not a very terrible one. You can go over it again, when you are disposed, the first time you meet with a carp.

Why have I taken the trouble to say so much about a miserable fish-bone, which you throw away without looking at? Simply because all these details are to be found in yourself, increased and perfected undoubtedly, as is to be expected in beings so superior to a fish; yet the similarity is such you cannot fail to recognise it.

The piece with the two holes is here called the body of the vertebræ, and, between ourselves, it bears the same name in fish; for we call indifferently vertebræ, in all the vertebrated animals, those numerous pieces, the uniting of which in them forms the great median column. Scientific men use the same terms to express the same

* On looking at the great bone of the fish as it lies on your plate, you would imagine that the ring in question is placed on the side; but it must be borne in mind that fish do not appear in their natural position on our tables. They are there lying flat, but observe them swimming, and their position is just the reverse; they cleave the water edgewise. In this position, which is their natural one, the spine of the great bone is directed upwards, and the ring very clearly surmounts the round piece.

things, irrespective of their belonging to man or fish; and it is owing to this general classification that the tiny kind of beads which you separate from the fish-bone, and which appear insignificant, has the honor of being called the body of the vertebræ, as much as if it belonged to the lord of creation.

It is true your vertebral column is not hollowed to receive a fatty pulp, which we find serves to unite the rings of the fish-bone. It is composed of a kind of small oval bone, almost entirely cellular, especially on the two surfaces above and below, which are flat, and pierced by an immense number of small holes, visible to the naked eye, as the microscopist would say. To these are attached fibres of a peculiar substance not to be found anywhere else in the body, the name of which will sufficiently indicate to you their mixed character. This substance is called fibro-cartilage, a name which should not alarm you, after all that has been said about cartilages, etc.

This fibro-cartilage performs in man the same office which the pulp fulfils in the fish-bone. It keeps the whole vertebral column in its place, but in a far more energetic way than its representative in the fish. The fibrous membrane, of which it is composed, adheres so strongly to the bodies of the vertebræ which it unites, that it requires enormous strength to separate them. Nothing is more firmly fixed in your whole frame. They are, however, interspersed with pulp similar to that in the fish, which is whiter and more abundant in children than in adults. Therefore at this moment you more nearly resemble fish than I do; not that I feel proud of the difference, inasmuch as the fibro-cartilage owes all its suppleness to this inferior order of pulp, whilst we men, in whom it will be found yellow, thick, and hardened,

should greatly prefer resembling the pike and carp a little more, and thus have the power of bending our backs as easily as you.

It is solely owing to the elasticity of the fibro-cartilage that the vertebral column can bend forward, for the bodies of the vertebræ are in such subjection that none of them can swerve from their place. You will presently see why it is an impossibility to bend the vertebral column backward, at least to any great extent.

These elastic cushions, placed one above another throughout the column, make some difference, as you can readily imagine, in its length, and consequently in the height of the human frame. Thus your body is shorter at night than in the morning. This may surprise you, but it is a fact.

You know, by experience, that a spring wears out with constant use; that old worn-out sofa-springs cease to yield when you sit down upon them. The same change takes place with the springs between each vertebræ; they grow weary with supporting the weight of the body all day, and at night become weak like the springs of a well-used sofa. This is why you regularly shrink in height towards evening, principally in the fibro-cartilages of the loins, which have the greatest weight to bear, and are the thickest into the bargain. No sooner are you in bed, and your limbs resting, than these little magic springs begin gradually to recruit; they recover their elasticity during the hours of slumber, and in the morning all fatigue has disappeared.

The difference in height, I must tell you, was not very evident the preceding evening, as in a small column like yours the contraction is very trifling, and we must examine very closely in order to perceive it. Still it exists, like many other things which we pass by unobserved. In

a tall person, the difference is sometimes very marked. Buffon asserts that he knew a young man of five feet nine inches, who, one morning, measured only five feet seven and a half inches, in consequence of having spent a night at a ball. We are bound to suppose that he had danced a vast deal. This explains the story of the conscript, who, being just regulation-height, walked all night before presenting himself at the military board of examination. He gained his point, for he was no longer of sufficient stature. Let me observe, however, that such changes only happen to young people in whom the fibro-cartilages are in a soft or pulpy state. Later in life they are too hard to yield in this manner. It is not unusual to find them ossified in old people.

Speaking to you of this conscript's trick reminds me of the gigantic skeleton of a whale that was exhibited in Paris a long time ago. I still, in my mind's eye, see the place where it was shown. Nothing remains so fresh and green in the memory as the souvenirs of our early youth. The animal, if I remember rightly, measured 150 feet in length—double the size of an ordinary whale. The public never regretted the money they had to pay for a sight of this wonderful phenomenon. A professor of the Zoological Gardens, puzzled by the advertisement, was enticed into the booth where the whale was shown. His experienced eye discovered the deception in less than two minutes. A plug of cork had been inserted between each vertebra by way of fibro-cartilage; and if the skeleton measured only 150 feet in length, it was pure modesty on the part of the exhibitor, for he might as easily, by lengthening the cork-plugs, have made it 200 feet.

I recommend you, in studying history, to call to mind, from time to time, this story of the skeleton of the whale.

You will read of characters who appear unnaturally large, but wait, before judging, to ascertain that nothing has been inserted between their vertebræ.

But we are playing truant a little with our fibro-cartilages. When you hear their names you will not think them very amusing. Still as we are not here for amusement, let us at once return to the vertebral ring, which we seem to be forgetting.

CHAPTER VII.

THE VERTEBRAL COLUMN—(*Continued.*)

The human vertebral column, like that of the fish, is surmounted by a throne-like eminence, from which it takes the name of dorsal spine. The ring formed by its being hollowed at the base is also triangular—at least in the greater part of the column—and the canal running from one vertebra to another, acts as a channel to a whitish cord analogous to the thread-like substance of the same color, which we noticed in fish. We shall say more presently about this cord, which is one of the great powers of the body. To-day it will be sufficient to teach you, that it is all called spinal marrow:—marrow because, like all real marrow, it resides in a bony canal; spinal, because of the spine which protects it from external shocks.

Whilst we are explaining the meanings of words, I may as well tell you the scientific name of this spine. It is called the spinous apophysis.

Apophysis! would it not be a pity to ignore such a word? Eliza is a pretty name, but—tastes differ. I find apophysis still prettier, although it comes from the Greek. After all, the Greeks were not altogether barbarians. In point of harmony, their language must be considered equal to ours.

Whether you consider apophysis harmonious or not, it signifies, in English, eminence. It is a term applied to

all prominences on bones, and will occur at intervals in the course of our study.

The ends of the spinous eminences, which are far from being finely pointed, being placed on the same line, meet whenever the column is thrown backward, thus opposing an insuperable barrier to any movement in this direction.

As to the base, it enlarges, in the shape of a blade, to form the walls of the vertebral canal, and presents at its four corners elongated protuberances with a smooth surface: the exterior surface for the pair of the vertebra above, the interior for those of the vertebra below. By means of these swellings all the vertebræ fit firmly into one another, the smooth part of each pair meeting the corresponding pair in the neighboring vertebra. This is why they are called articular apophyses, and, in fact, we find in them a real articulation, with its gliding cartilages, its synovial membrane, and its ligaments.

Other ligaments, which enclose, as it were, the bodies of the vertebræ and the spinous eminences, or apophyses, add further to the solidity of the whole; as the blade-like parts of the spine are not exactly adjusted to one another, the interstices are filled by ligaments of wonderful power, which effectually complete the closing of the canal.

It is a long time since I first became acquainted with these ligaments; they attracted my notice when I was a child, and I used to try pertinaciously, but always in vain, to bite through the mass of yellow fibres which we sometimes find attached to boiled beef.

My mother told me that it is called the *tirant*, a word which appeared to me then very appropriate, and as the learned men have not given it in any of their books, I have, to reassure myself, looked for it in a pretty little dictionary that I have, to which I refer occasionally

when I am at a loss about the orthography of a word. Here is what I found :—

TIRANT,—*Yellow nerve* found in the meat of the butcher's shops.

From which I concluded that one should always mistrust the dictionaries, especially that of *a moins que ce ne soit celui de* M. Littre.

The learned name *tirant* is the *yellow nerve ;* and I must say that I find the name charming. I must own, that it strikes my eye every time I encounter it in the books, which piled up before me. I remember my earliest studies in Natural History and under whose eyes I made them.

Having given you a general description of the vertebræ, the different kinds must now come under notice, for they are not all alike ; some indeed, among the number are very different from the idea you will have formed of them. First, then, how many vertebræ are there ?

You probably think, with my experience, and so many books on the table before me, that I can at once answer your question ; if so, you are mistaken ; with only one book, I should feel less puzzled.

Bichat, a genius who died at the age of thirty-three, the period when a scientific man is usually but in his apprenticeship, ranks indisputably among the masters of modern science. Bichat considers the vertebræ to be twenty-four in number. Milne Edwards, whose authority in such matters appears equally reliable, says he finds thirty-three. I should like to name a still higher figure —not on my own responsibility, rest assured, but on that of Goethe, Geoffry St. Hilaire, Carus, Owen, and other names, the enumeration of which might alarm you by their number, if I were disposed to overwhelm you with a display of my learning.

To avoid all discussion, I will begin with the vertebræ of the neck, about which every one is agreed.

They are seven in number, and the first and second deserve a special mention.

Be honest, and tell me whether you have ever given yourself the trouble to remark and admire with what facility you turn your head whenever your curiosity is excited? Perhaps you imagine it performs this movement without any assistance—that it is its own master; if so, understand from this moment, that all its movements are the result of a very delicate mechanism which it is most important to comprehend, especially as ignorance on this point exposes a person to the danger of unwittingly killing himself in some cases; or, what is still worse, of taking a fellow-creature's life without knowing why. It is less trouble to remain ignorant, but ignorance is not always bliss.

It is not the skull which pivots on the vertebral column when we turn our heads; thanks to solid ligaments, its lower extremity is firmly fixed in two pretty deep hollows made at the apex of the first vertebra of the neck, and the pivoting takes place at the base of this vertebra, which accompanies the head in all its movements. You quite understand that it would never do here for the body to be firmly held by the fibro-cartilage, nor for the apophyses to be fitted one into the other. The motion of the vertebra would, in such a case, be too circumscribed. Thus it is simply a bony ring partially rotating, without impediment, on the vertebra beneath, the apophyses of which are flattened obliquely in order to leave to it an entire liberty of action, and the articular ligament, which is very supple, readily accommodates itself to considerable changes of position. Finally, to support the circle in its rotatory movements, and to prevent

its leaving the surface upon which it glides, a small bony cylinder springs up from the second vertebra just between the two hollows which receive the extremity of the skull, and acts like a peg upon which a hoop oscillates.

Before we proceed, let us inquire into the names given to these bones, in awarding which imagination has aided science.

You have an atlas of geography, but can you tell me the derivation of its name? It comes from the giant Atlas, who, as the Greeks say, carried the heavens upon his back; the same giant who was afterward transformed into a chain of mountains—the Atlas of Algiers, the name of which has been given to its neighbor, the Atlantic Ocean. He who could carry the whole celestial sphere would surely have strength to bear the weight of our small globe. Ancient geographers used to draw the giant with his large back supporting the globe, hence the name atlas, so familiar to all geographical students. Ancient anatomists on their part thought nothing less than an atlas was necessary to carry this other globe which we all support on our shoulders; a globe as heavy as the other, when we take into consideration all that it is capable of containing, and they thus gave the name of atlas to this first vertebra of the neck upon which the head reposes.

Speaking of geography, you must have heard of the axis of the earth—the line that runs from pole to pole, and upon which the earth turns during its revolution round the sun. The axle of a wheel is the axis on which it turns. The second vertebra in the neck is also an axis, because its peg is the pivot upon which the head performs its rotatory movements. Thus they have named this second bone axis, a Latin word requiring no further explanation.

In a word, this little bony cylinder, this peg, this pivot which renders you such essential service when you play at hide-and-seek, has been found upon close examination somewhat like a canine tooth in appearance, with a protuberance behind, consequently the cylinder has been named the odontoid eminence, or odontoid process, a Greek word, but when I explain to you that odontalgia means toothache, you will understand its signification.

The history of these two vertebræ does not end here. Liberty of movement is a very charming thing, but we are not permitted to enjoy it gratis ; liberty and wisdom require to walk hand in hand, and, notwithstanding the ease of movement peculiar to this atlas, a single act of imprudence on its part might prove fatal. It has no fibro-cartilage, as we have said, to keep it in its place. Our friend, the yellow ligament, that powerful bond of union of the other vertebræ, is also wanting ; it would be too troublesome a guardian. It is true that the odontoid or tooth-like apophysis effectually opposes all backward horizontal movement, but for upward and downward movement it is like the hoop kept in its proper place by the peg ; it rises the whole length of the protecting cylinder, and loses its equilibrium in proportion as the top of the cylinder tapers off into a sharp point. Suppose now that the head were violently lifted up at this moment, it would drag the atlas to which it is fastened by ligaments, along with it, obliging it to leave its post at the level of the odontoid apophysis. In this position a strong shock given to the body would displace this apophysis, making it slip out of the ring, which would be thrown backward, and thus produce strangulation of the vertebral canal. The spinal marrow, which was lying at its ease within this canal,

would suddenly find itself compressed by the intruder invading its domains, and sudden death would be the result. You will know the reason of this when we come to the history of the marrow.

Always remember never to lift, or allow another person to lift, a child by the head, as people often do without thinking of any harm or risk. In more than one instance, children struggling to escape from this unpleasant position have been instantly killed, in the way I have just described, at the hands of their affrighted tormentors. I hope you have never watched any one kill a poor rabbit, but, without seeing such a thing, you will be able to understand that these animals are deprived of life in a moment by pulling the head and tail in contrary directions. The atlas is displaced, and death is instantaneous.

To remove any uncomfortable impression resulting from what I have just told you, I will give one more example of the unconcern with which people, little thinking it, often trifle with death. There is a game, by no means a pretty one, which is often a great favorite with boys—viz: turning heels over head. The head is placed upon the ground as a point of support to the whole body, which passes over it; the slightest false movement would suffice to dislocate the fragile joint of the atlas, and the child would turn over on the other side a corpse. Let us be very thankful this does not oftener happen. Mothers should take warning!

You see, my dear child, that if patience is required in order to store all these complicated details in your mind, all these new words—fibro-cartilage, axis, odontoid apophysis—which, no doubt, are rather wearisome to you, in spite of all I have been able to say in their favor, you see that, setting aside the satisfying of your curi-

osity, there is a decided advantage in knowing how you are made. Young and old are alike interested in it; ignorance exposes them both to the same dangers. Were I Minister of Public Instruction, I would have these things taught in every village school; and no one shall ever persuade me that the world would be any the worse were all the nursery maids made acquainted with them for the good of those intrusted to their care.

I have nothing to tell you about the last five vertebræ of the neck, unless it be that they are smaller, finer, more easily moved than those in the rest of the column; their mobility is chiefly owing to the oblique form of the articular apophyses, which are bevelled, which gives them freer play, and to the feeble development of the spine, the points of which projecting but little, have a longer journey to make before meeting each other. Thus the region of the neck is the most flexible part of the whole column, and if the movements peculiar to it were withdrawn, only leaving those of the atlas upon its axis, we should find it inconvenient to look behind us.

The region of the back is quite another affair; in it there are twelve vertebræ which scarcely move, so firmly are they packed together. The articular surfaces meeting in a straight line mutually lessen each other's power of motion. The spinous process, being elongated, reposes on the process of the vertebra below it, and partly covers it. All these taken together render the region of the back almost immovable, and not without reason. Each of these twelve spinal vertebræ has at its side a bar of a cage we are soon to speak of, which would run great risk if its point of support were liable to move sometimes to one side, sometimes to another.

There are only five vertebræ in the region of the loins, but each is six or seven times the size of the small verte-

bræ of the neck. The spinous apophyses project considerably outward; but they are sufficiently removed from one another to leave the vertebræ a little room to play, especially the first, the articular surfaces of which are slightly rounded, and accommodate themselves more easily to a gliding motion.

The last vertebræ of the back being more flexible than the others, that part of the column where the back and loins unite has the most flexibility. It is owing to this that tumblers and jugglers succeed in doubling up their bodies. Nevertheless, the softness of the ligaments in early youth would not suffice for this kind of work, were the miserable creatures, whose trade it is to teach it, not aided in their infamous calling by something else. I have already told you, that the ends of the bones were in the first instance like cartilage: now the large apophyses of the lower vertebræ, while passing through this stage, can be bent in any position, and they will afterwards maintain it during the process of hardening. This is what is familiarly called breaking the backs of the poor children. Their backs are not broken, as you see, but are pretty nearly so.

Seven vertebræ of the neck, twelve of the back, dorsal, five of the loins, lumbar, make up the twenty-four admitted by Bichat. We still want other nine to complete the thirty-three Mr. Milne-Edwards assures us are to be found. They do really exist, but so different in appearance from the other vertebræ, that we can in some degree understand the scruples of the great anatomist who assigns them a separate place.

First of all, there are five vertebræ welded together so as to form one single bone, bent inwards at the base, where the vertebral canal terminates. This bone is called the os sacrum, or sacrum,—to call it by its Latin

name—but I must plead ignorance if you wish to know why it gets such a fine name.

The vertebræ of the os sacrum are quite distinct for a long time : they only unite after a certain period, and in fact this os sacrum, with its magnificent name, is simply a smuggled bone, the result of a coalition. It is but justice to give to the spinal column the five vertebræ of which it has been slyly deprived. We may say the same of the four very small vertebræ which follow the sacrum ; in the first instance separate and distinct, they by and by unite and form a single bone, which itself often becomes one with the sacrum ; but, however imperceptible these bones may be, their title to the rank of vertebræ cannot be denied. They are, in fact, the tail of the column.

The vertebral column, as we have now passed it in review, with its thirty-three vertebræ and their rows of apophyses, has also certain curves which cause it to resemble, when seen sidewise,—can you guess what?—a caterpillar, with its head half raised as it crawls along.

In order not to disgust you, my young friend, I have made it a rule to dispense with those ugly anatomical pictures, which would have been most useful in my explanations. For once, however, I cannot resist the temptation of showing you one taken from Mr. Milne-Edwards' zoological illustrations, where, if you wish, you can see many others. This very faithfully represents the appearance of the vertebral column. Is it not very like a caterpillar climbing up a cabbage ? What makes you laugh ? The tiny tail ? Nevertheless the vertebral column terminates

exactly in this manner. Those are the poor little vertebræ at the end, and there are some very much like them to be found in your cat's tail.

Now you will say, "What is become of the other vertebræ, since you tell me there are more than thirty-three?"

Where? Why, at the other end of the column, so let us pass at once from the tail to the head.

CHAPTER VIII.

THE HEAD AND CHEST.

Goethe—one of the greatest names in literature, a poet alike in prose or verse, a man of science even in his leisure moments, and one who has done more for science than many who make it a profession—Goethe tells us in his memoirs that, as he was one day walking on the Lido sands, close to Venice, he noticed a sheep's head on the ground, which was split in the most perfect manner, and on examining it he felt himself confirmed in an idea he had previously formed—viz, that the skull bones were only vertebræ in another shape. None but a poet would have had such a happy idea, and it is a pity, both for science and for themselves, that literary men are not more frequently inspired to study the laws of nature. Genius may find subjects for investigation everywhere. Assuredly but few of the scientific labors conducted in the laboratory or the study have been more fruitful than this stroll of the poet lounging on the banks of the Lido, if it be true, as Goethe asserts it is, that this sheep's skull first revealed to him this primary law, of which I have already often told you, and which he first introduced into the scientific world; a law in accordance with which all organic structures have been made, and which is always modifying and perfecting itself.*

* This is the quotation from Goethe's memoirs, which you can read to your papa if he has any curiosity to see it:—

" During one of my frequent rambles over the downs of the Lido,

It seems very strange to you, does it not, that after all we have said of the vertebræ, we have to search for some of them in these thin, smooth, rounded plates which form the arch of the skull? As for myself, let me tell you in confidence, the first time I heard it I thought it was only a jest, but reflection has induced me to change my opinion.

When we come to study the nervous system, and, above all, when we follow out its transformations in animals, it will be easy to convince you that the brain is nothing more than a prolongation of the spinal marrow, enlarged and perfected, as one might say. This acknowledged, it is but a step further to admit that the skull, this bony covering of the brain, is only a continuation of the bony canal in which the spinal marrow is enclosed. Thus we have a perfect right to consider the different pieces which compose the skull as so many vertebræ, and to add them to the thirty-three we already have.

The difficulty is, to tell you how many we here find of these vertebræ. Goethe counted six; Geoffry St.

which separate the Adriatic from the Lagunes of Venice, I found a sheep's head split open in the neatest manner, which not only confirmed the great truth I had already discovered—viz., that all the cranial bones were transformed vertebræ, but also made me understand the process of gradual improvement and development by which shapeless organic matter attains a higher organisation; and then my old belief revived, strengthened by experience, that Nature has no secret she is unwilling to reveal somewhere to the attentive observer.

"I was fully convinced that a universal type existed among all organised beings, rising in perfection by means of gradual metamorphoses, and that this type might, with certain restrictions, be easily recognised in all parts of their organisation, and that it could be equally discovered where it is most deeply concealed—namely, in man, the highest type of organised being."

Hilaire, seven; others again find only three, whilst many hold that there are four, and this would be my own opinion, if I dared to express one on a question about which scientific men are not agreed. To feel myself at ease regarding them, I shall shut up all their books, and retain only one open upon my table. It is true all the others have been made from this one, for it is a skull.

You can follow me quietly with the point of your finger on your own skull, it will not alarm you, I imagine, so well covered as it is; and do not be frightened beforehand at the names you may hear. When they are too ugly I will spare your feelings by passing them over.

First, touch the back of your head, at the spot where it joins the neck. What you feel there is the occipital bone, and if you want to know from whence it derives its name, look out the word occiput in a dictionary. You will find that it signifies the back of the head; it is the opposite of the sinciput, which means the top or summit of the head.

The occipital bone rests exactly on that atlas of which we have spoken so much, and it is pierced below with a large round hole, through which the spinal marrow enters the skull, where it spreads itself out in a wonderful manner, as we shall presently discover.

You see at a glance that this is a vertebral bone; it bears the mark of its origin, and presents at the entrance of the canal its two articular apophyses distinctly characterised.

Under each ear you have a little hard lump, very easy to find. It is the mastoid apophysis, a formidable name which you will easily remember on that account. I may as well tell you in passing, that to these points are attached the muscles which draw the head to the right or

to the left, causing it to pivot on the vertebral column. Carry your finger from one to the other, making it describe a kind of semicircle, the convexity being upwards. You will very nearly follow the upper border of the occipital bone, irregular in its form, and somewhat resembling the teeth of a saw, by means of which it is firmly dovetailed into similar indentations of the bone above it.

This latter bone forms the arch of the skull, and its name, moreover, suggests the idea of a piece of masonry. It is called the parietal bone, from the Latin word, paries, a wall. It is the largest bone in the head, only the welding which unites the two parts of the contiguous bones in the centre, both front and back, is not found here. This weld is replaced by a zig-zag suture, resembling that which borders it on all sides, and unites it to the surrounding bones, so that to any person looking at a skull, these two parts appear to be two separate bones. For this reason anatomists in their books mention two parietals, but that does not prevent us reducing this contraband pair to unity. So we will look upon it as the second vertebra of the skull, of which it forms the principal piece.

Now put your finger half way between the tip of your ear and your eye, on the spot called the temple, and draw a line toward the other temple, in the same way I made you do over the occipital bone, but making the bend incline a little further back, and you will follow the suture by which the parietal vertebra is connected with the third bone, the name of which requires no explanation, it is the frontal bone, or bone of the forehead.

There is this satisfaction with these bones, especially with the frontal, that their form does not require to be described. You can ascertain their shapes yourself, either in the mirror or with your hand, better than in any book,

for the all-sufficient reason that they vary in each individual. High, low, round, flat, spacious, narrow, the forehead differs in every human being ; and without attaching any real value to this difference, I shall show you by and by, that generally these distinctions represent some decided difference of character ; but if the frontal dimensions are variable, its boundaries are everywhere the same.

Separate the forefinger and thumb, and place the curve of your hand over the brow, where the nose commences ; on pressing on the orbit of each eye with the fingers, exactly at the little prominence which you feel at each side, you will thus touch the three anterior points where the frontal bone terminates. It extends backward to the extremity of the little cavern within which the eye dwells with all the guarantees of security suited to so important an organ, and then joins itself below with an irregular mass of protuberances, points, and bony eminences, which extend into the interior of the head as far as the occipital orifice.

Within this orifice are to be found parts known by all kinds of strange names, quite useless to you, and so I shall decline giving you any explanation about this region, which completes the fastenings of the cranium below, and which in living persons is perfectly inaccessible to observers, hidden as it is in its depths.

The longer I contemplate the skull I hold in my hands, the more natural it appears to find in it a body of vertebræ. If you recollect what I recently told you, it is the body of the great cranial vertebra of the parietal, which is attached to it on either side by two prolonged processes, of which the principal, called the temporal, supports the ear, and terminates above at the temple—hence its name.

The skull will thus be found to be composed of three vertebræ, one in front, the frontal; the second behind, the occipital; and the vertebræ of the centre which, under the various names of parietal, temporal, etc., etc., make up the whole. All this is clear, and easy to remember; and as we have come to this conclusion, we will not ask anatomists for their opinions on the subject.

And this fourth vertebra, you will say, what are you going to do with it, seeing the entire skull has been completed? Do you remember the small vertebræ at the extremity of the spinal column, which seem only rudimentary, forming in reality no part of the vertebral canal, seeing that the marrow does not reach them? They have a counterpart in a very small bone, which forms a direct continuation of the frontal, extended on the median or middle line, and seems to be the last effort of nature in her completion of the vertebral column. Whilst we have been speaking of this column, I have more than once pictured it to myself as resembling a large walking-stick terminating in a point, the head of which would be the cranium. The bone we are talking about, the fourth vertebra, without office, would thus be a kind of ornament added to the head. And, indeed, it might truly pass for an ornamental bone, as it contributes greatly to the beauty of the face, inasmuch as it is the bone of the nose.

I can fancy you putting your hand to your nose, and thinking me very bold to compare it to a vertebra. You allow that appearances go a long way with you. The handsomest nose in the world—your own, if you like—has only an ugly rudimentary, or imperfectly formed, bone for its foundation, which stops at the bridge, as it is called. The remainder, to make use of a comparison that I sincerely hope will soon be out of fashion, the re-

mainder is but a little crinoline of cartilage which has usurped the place it occupies. It is principally on this account that the face of a dead person is not pleasant to look upon, as only the really solid portions are left, and an ugly orifice replaces those elegant wings or nostrils, which are the great charm of a beautiful nose. For this reason ancient poets called death the flat-nosed one, as if to defy it at a distance. All noses are flat when they lose their little cartilaginous crinoline, whether aquiline or snub, it matters not.

With the nasal bone, whether considered as a vertebra or not,—between ourselves, it is of no importance—begins the series of what are called the bones of the face.

Of these there are a great number, fourteen in all, if I give you the official computation, but I shall abridge them and only mention the three principal ones, which properly speaking we have close at hand.

The first of these is the cheek-bone, of which there are naturally two, as each cheek requires one bone. One part rests upon a long projection springing from the temporal to support the cheek in front of the corner of the mouth; the other upon the upper jaw just above the molars, and goes upward to rejoin the frontal at the spot where you just now placed your finger. This is quite a geographical study, you see. But I think it would have been a great pleasure to me to have been able to pass my finger over my cheek when I was a little boy, and tell the name of everything it met with there. Unhappily, at your age I knew far less than you do, and so it is, the world progresses generation after generation, each one making an advance in knowledge.

The second bone you have to examine is the upper jaw. Like the parietal bone its two halves only meet in the middle line, and are separated by a very percept-

ible wall. But there also the weld seems only to have been forgotten, so I shall not adopt the custom of considering it as two bones—it is only one with a cleft in the middle.

The upper jaw is the important part in the arrangement of the facial bones. It extends alongside the nose up to the frontal, with which it articulates almost upon the same line as the bone of the nose, which it encloses between its two nasal processes, so to speak, as in a frame. We have seen that it extends from the side under the cheek until it meets the cheek-bone. There the inferior surface remains which forms the whole roof of the palate within the mouth, excepting a small band at the bottom which is separated by a wavy line which has been classed as a distinct bone under the name of palate-bone. I should be sorry to cavil about this bone, but could we together examine it uncovered, I am sure you would agree with me, that it is simply a piece of the upper jaw in which the weld has been forgotten.

If we had not already studied the teeth at full length, I should have many things to tell you about those valuable little pearls of which your jaws are the jewel-cases ; as the ground has been already gone over, it would be useless to recommence with them.

I might almost make the same remark respecting the lower jaw, the third bone of the face, which I wish to talk to you about. When treating of mastication we discussed this bone, and later, when referring to the lion, I was under the necessity of explaining to you its articulation ; its most curious feature, that which most merits our attention, is, that it is the only movable bone to be found in the head. But we have enough to do with what you are still ignorant of, without going back to what you know already.

Anatomists consider the lower jaw to be only one bone, because its two parts have the good nature to unite in early life; if you wish to know the reason, it is easily ascertained. The lower jaw works hard, and bestirs itself, whilst the other lacks energy to unify itself, if I may be allowed the expression, its idle halves lazily waiting the shock without meeting its antagonist half-way, while the lower jaw rapidly unites its halves in the incessant effort of a common action. Nothing so greatly promotes union as acting in concert, and what happens in the jaws occurs also in society. Take a party of little girls, for instance, divisions quickly disappear when they all agree to play at the same game. I mention this as an example you are probably acquainted with, though no doubt others might be cited with advantage.

To return to the bones of the face which you will lose sight of if we chatter so much over our philosophy, it was there Goethe found three out of the six vertebræ that he saw in the sheep's head.

"There are," says he, in the beautiful language of an observing artist, which you must get some one to explain to you, "There are three vertebræ for the posterior portion, enclosing, as we may say, the cerebral treasure, and the terminations of life delicately ramifying and spreading out like branches in the interior; three vertebræ from the anterior portion which have communication with the external world, and which apprehend and comprehend it."

The idea is certainly beautiful, fitted to captivate a poet, and in spite of myself makes me think of an impious remark made by a compatriot of the great naturalist, "Had Goethe been by when the world was created, he might have given some hints." Unfortunately the

vertebræ were all arranged before his day, and although I have studied and restudied my anatomical skull, I cannot bring myself to agree with Goethe as to the authenticity of his three bones. We scarcely see in the bones of the face anything beyond appendages to the great central vertebra, mere accessories to the vertebral system, but having themselves no place of their own in it.

This character, already pretty apparent in the cheekbone and even more visible in the lower jaw, becomes self-evident in another series of bony pieces, which seem to be a repetition, the first especially, of the lower jaw, and no one has ever felt inclined to consider them as vertebræ. I speak of the bones in the chest.

You may read over again the description of the chest that I formerly gave you. It will interest you more now that you know a little about the construction of the bones, and that you have made the acquaintance of the vertebral column which acts as a basis to the chest bones. You only require now to see what I have described set in motion.

I have related the movements and workings of the diaphragm at some length; this model servant of the good old times, who does duty for the lungs without our troubling ourselves about it. Hitherto I have spoken of it separately; but it has assistants in those twelve pairs of bars which diverge right and left from the dorsal vertebræ to form the thoracic cage. I must tell you in passing, that this term is taken from the word thorax, a Greek word signifying chest, and one we shall presently require to make use of.

You know the first seven pairs of ribs are supported on a bony plate called the sternum, or chest-bone, which unites them all, and which closes the cage in front oppo-

site to the dorsal vertebræ, which close it behind. Here, then, you find the ribs are held fast at both ends, and at first sight you will be unable to perceive how they can possibly assist in the dilatations and contractions of the lungs; but nature has many an artifice.

These ribs are not hard throughout their entire length; at the two points where they join the chest-bone and the spinal column, they terminate in cartilages, which possess a certain degree of flexibility, and which never completely ossify except in extreme old age. Moreover, they do not form a regular curve. Picture to yourself the two halves of a hoop slightly twisted inwardly and obliquely one over the other, and you will understand what I mean.

What takes place when you pull the cord of a Venetian blind, of which the bars are inclined downwards? They all rise, turn their lower edge outward, and without the frame moving, a space is immediately made through which air and light enter the apartment.

It is just the same with our ribs, small cords run between them from one to the other, the names of which are not very alarming. They are called intercostal muscles. When the moment comes for dilating the lungs, all the small cords become stiff. The ribs raise themselves by slightly twisting the cartilages, which easily yield. The inward curve becomes an outward one, and the cage is immediately enlarged at the sides, whilst the diaphragm elongates it by descending towards the abdomen. Do not forget that the sternum is itself elastic, seeing it is intersected by cartilaginous bands, and that the heaving of its sides pushes its lower point outward, which so far increases the space in the chest. All return to their place the moment the diaphragm ascends; and the lungs, compressed into a space

which confines them at once on every side, are soon obliged to expel the superfluous air.

I hope, dear child, this will help you to understand why your mother thinks it so necessary you should stand and sit erect. When the body is left to itself, and the shoulders weigh on the chest by bearing on it, all this rise and fall of the ribs is only partially carried on, because the slender cords as they stretch themselves are unequal to the task of raising up the shoulders, an enormous weight for them, respiration is but imperfectly carried on, and the entire economy suffers, for we have already proved that to live and breathe are synonymous. But there is something still more serious in this than momentary inconvenience. All these cartilages, so pliable at your age, take a false bend for want of the proper movements assigned to them. The chest is arrested in its development, and the least evil resulting from it is to find one's-self when grown up, I will not say humpbacked, for that is not always the case, but bent double like an old person before our time. This will come soon enough, believe me, without seeking it.

I have still some advice to give you about these delicate and precious little ribs, the movements of which are of great importance to you. It can scarcely be useful to you until you are a little older; but never mind, take it whilst we are on this subject, you can keep it for by and by. It is hardly necessary to tell you that a certain article of a young lady's dress is tightened by lacing to give her a fine shape; the mischief is not very great when the lacing is drawn in moderation, but from what I have just told you, you will easily see what inevitably happens to all foolish girls who aim too energetically at possessing a figure like that of the wasp. If the bars of the Venetian blinds were very firmly

wrapped up and then bound round with string, you might pull away at the inner cord but nothing would move. This is precisely the trick this murderous lacing plays on those who pull it with all their force.

Why thus heedlessly set at naught the wise arrangements of Nature, who has planned everything so as to leave freedom to the movements of the chest? The best gift she can bestow upon us here is a capacious chest, in which the great organs of life have space enough to work at their ease. It is a great misfortune when the chest lacks capacity, and the lungs consequently are confined within too narrow an abode. A defect of this kind often induces feeble and delicate health, too often ending in premature death. To reduce of our own free will a naturally well-formed and capacious cavity, is worse than folly, it is almost a crime, seeing that it is the first step towards suicide. When you shall have grown up to be a big girl, never lace your corsets too tightly. Begin at once to hold your body erect. Throw your shoulders back so as to spare the cords of your little ribs, and thus you will find out how useful is the history of the twelve pairs of ribs and the sternum.

CHAPTER IX.

THE ARMS AND LEGS.

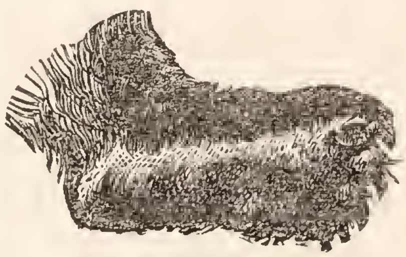
We now enter upon the real territory of the bones.

Up to the present time we have only met with bones occupying, if I may so speak, a secondary position. The vertebræ and the ribs are, properly speaking, only the casings; the bones of the face are but accessory pieces without movement, and, so to say, without function. The lower jaw is the only bone we have seen really playing an active part, and it is but partially free, held in check as it is on all sides by bands and ligaments. In the arms and legs the bones are lords and masters; they occupy the heart of the place, and the others group themselves around them to serve them in their function, which is to transport the body and to seize upon the objects around it.

Travellers tell us that African negroes can steal with perfect ease by means of their feet, and in public shows you may sometimes see mountebanks walk upon their hands with their head downward. Little boys sometimes think this very delightful, and torture their wrists in imitating them. The arms and legs can, then, exchange functions when required. This is because our four limbs are all made after the same model, with slight differences, determined by the difference of their functions, and this again is an example of the way in which Nature varies her productions, still preserving the model in which they are formed.

We have two animals in our Zoological Gardens which teach us with what ease nature converts our arms into legs, and *vice versâ*. The bear frequently deprives sportsmen of their lives by hugging them against its chest with its fore-paws, using them as arms; and the monkey exhibits a species of hand at the extremities of its legs.

Look well at this little woodcut.



It represents a bear's paw. Could you not almost believe it to be the sole of a human foot? It would seem as if Nature had intended to put feet on the arms of the bear and hands on the monkey's legs, modifying, consequently, the two pairs of members thus perfected.

If this be true, you may expect to find a great similarity between the arm and the leg, and such will prove to be the case; but you must not complain, for it will render our study of these limbs easier and more interesting.

First we will notice the arm; it is right to begin with it, for in this manner you carry out Nature's laws.

Have you ever remarked in infants, whose legs are utterly incapable of supporting the weight of the body, how strong by comparison their arms are? and how dangerous their little hands, so delicate in appearance, are even to a man when by chance they grasp his beard? This has happened to me more than once. There is a

reason for everything, and the reason for this difference between the strength of the arms and that of the legs is because the bones of the arms are ready for work long before those of the legs. The foot is still in a half cartilaginous state, while the bones in the hand are almost completely formed; and from the fingers to the shoulder, all the bony part of the upper limb is equally in advance of the corresponding part of the lower one.

This is a lesson Nature teaches all of us, my dear child. Before we can act, knowledge is necessary; therefore, the hand, which serves to educate the infant; the hand, with which it touches all it sees to confirm the still uncertain indications of an inexperienced eye; the hand, so excellent a preceptor, is perfected before the foot. The latter is a passive attendant destined to come into use afterward—to bring him face to face with difficulties and dangers, when he shall have learned to understand or appreciate them. If, then, you should happen to be left at school after your elder sisters have been introduced into society, do not consider yourself ill-used. When the hand has accomplished its preparatory duty, the foot will take its turn.

The arm is supported in its movements on a large base fixed to the trunk, called the shoulder; it is composed of two bones, the scapula and the clavicle.

The scapula is easily found. Put your hand to your shoulder-joint, at the place where soldiers wear their epaulets, and move your arm up and down. You will feel a bone, which appears to dance with every movement of the arm: that is the scapula. Mind you do not put your hand too near your chest, or you will feel the clavicle instead of the scapula. You can easily find out if you have made this mistake by passing your finger so

far as the sternum, on the top of which the clavicle rests.

Underneath the point just indicated, a round hole exists in the scapula, into which the bone of the arm enters, whence it, the scapula, descends in a triangular form, the extremity of which you can touch by passing one hand under the arm-pit. This part of the scapula extends almost as far behind as the vertebræ, but it takes care not to approach near enough to articulate with it. It would no longer possess sufficient liberty to accompany all the movements of the arm as it now does; and so essential to its action is freedom, that it has not even a fibrous capsule binding it to the vertebral column. It is simply fastened to it by muscles, and this is the only example I can give you in the human body of a bone playing freely without being tied to its neighbors by this tough covering, of which the fibrous capsules are composed.

A certain solidity is, nevertheless, necessary to this movable foundation; it must be placed upon something firmer than muscles. Such is the service rendered by the clavicle. The clavicle articulates with the sternum on one side, and on the other with a large apophysis of the scapula, which exactly forms the point where the epaulet is placed. The clavicle is a kind of cross-beam, placed like a buttress, which retains the scapula in its right place, preventing its being driven against the chest by any sudden shock. The articulation is, otherwise, one of the most simple. Suppose a wand fixed at its two ends, and see-sawing upon the sternum as the scapula rises and falls—here, indeed, a powerful fibrous band is necessary, and the capsule, fastening the extremity of the clavicle to the sterum, presses so closely upon it, that the clavicle cannot be dislocated without breaking the capsule.

Between the scapula and the clavicle which supports it, there is a space filled exclusively with muscles. This space forms a hollow in thin children, which you have probably more than once observed.

The chief office of the clavicle is to permit of the arm being extended from the trunk, and to act as a support when the arm is crossed over the chest. Thus the clavicle is only to be found in animals to which this movement is familar, as, for instance, the ape and the bear, the two neighbors we recently alluded to. Watch a squirrel as he nibbles at a nut; by the way in which he turns and twists it between his two fore paws, which meet just at his little nose, you can assure yourself that his clavicle is in good order. The cat, and especially the dog, which use their fore paws to less advantage, have, instead of a clavicle, only a small bone suspended in the muscles, retained by ligaments to the scapula and sternum, which it does not touch. The horse, which uniformly moves its four legs in a straight line, has no clavicle at all; and the ass of La Fontaine, who wished to caress his master, in order to have done so elegantly, would have had need of a clavicle which he had not. On the other hand, in birds, where much strength of wing is required to support them in their flight, the clavicles have so important a part to perform, that, to increase their solidity, they are firmly knit together, and form but one bone, which is shaped like the letter V, the two branches forming to the scapula a point of support, at once solid and resisting. Ask to look at this bone the next time you see any one carve a partridge; it looks like a small fork leaning against the sternum; hence its name, furca, the Latin for fork.

Perhaps I ought to have reserved this for a later lesson, but I could not allow so excellent an opportunity to

escape me, of giving you an idea of the way in which the organs of relation are modified in proportion to the importance of their functions in the different animals, and how they disappear one by one, leaving intact the leading features of the plan on which they are grouped or classified. The clavicle is the first among the important bones in the human body that does not respond to our call, as we review the bones of those animals next below man: the movement over which it presides is to some extent an entirely human one, as you can understand if you watch a dancing bear or a tumbling monkey at its games.

Moreover, we need not turn to animals in order to observe the modifications of the clavicle, modified by the difference of the functions they have to perform. I can give you a curious example of this without going farther than the human species. Can you believe me when I tell you that, making due allowance for the difference of size, your mother has a longer clavicle than your father? This is, nevertheless, the case, and in little girls too, the clavicle keeps the scapula at a more respectable distance from the sternum than in boys, because it is proportionately longer in the former. Throwing stones is not a ladylike occupation, but it may for once be excusable on the plea of scientific interest. Let a boy and girl each throw a stone at the same moment; owing to the length of her clavicle, the little girl cannot throw her arm forward with the same ease and neatness as the boy. Ladies who might wish to amuse themselves by throwing stones, would never succeed in sending them any distance for this same reason; nor could they give a good blow with the fist even had they strong arms, which are sometimes to be met with in women. It is a kind of inferiority of which they need not complain, for

the result is more precious to them than the power of boxing. Give to the strongest man a child to carry in his arms, and he will soon be tired of the weight; whilst a small, slight woman will carry it for hours together, and never complain; thanks to the extra length of her clavicle, which allows her arm a more convenient point of support as it crosses over her chest. Now, observe how an inch more or less in a bone only the thickness of your finger assigns the part each should play; to the woman, that of carrying the child; to the man, that of defending both.

Let us now proceed to the history of the arm.

Without much study you can see that the arm is divided into three portions, which may be easily recognised. One extends from the shoulder to the elbow, the second from the elbow to the wrist, and the third from the wrist to the end of the fingers. These are, properly speaking, the arm, the forearm, and the hand.

There is only one bone in the arm, the humerus, the form of which you will find it difficult to ascertain, owing to the thick layers of muscles with which it is covered. Examined in a skeleton, it presents three longitudinal ridges, especially in the centre, for it is rounded toward the shoulder, and flattened toward the elbow, forming so convenient a leaning surface when you fall asleep with your head resting upon your hand

Only the two extremities of the humerus deserve our attention.

The upper extremity at the inner side forms a sort of half ball, and is called the head of the humerus; it fits into the round hole in the scapula, of which I spoke to you very recently. If you have ever remarked an embroidery frame, you can form a tolerably correct idea of the articulation of the arm and shoulder. It is by means

of a similar mechanism that the circle upon which the piece to be worked is stretched, the tambour, as it is called, inclines at will in every direction. The foot which holds it is screwed on to a ball, which can turn in any required way in a hollow half sphere. Only, as the arm requires to be always ready to move, the screw that presses the articulation of the frame, and fixes it in its place, would have an injurious effect here, and naturally we have nothing of the sort. More than that, the cavity, into which the head of the humerus passes, has not even depth sufficient to receive the whole of it; thus more liberty is given to the joints, at the expense, it is true, of its solidity; but this is a law we know already.

To add to this precious liberty which so facilitates the movements of the arm, the fibrous capsule of the joint is only incased in a loose bag, in which the head of the humerus moves with ease in its cavity. This capsule is so long that, in cases where the arm and shoulder are pulled in contrary directions, it allows the surfaces of the two bones in contact to separate almost an inch, which could not occur in any other joint without breaking it. In these cases, the head of the humerus leaves its cavity, and, if the neighboring muscles did not retain it in the right direction, as they stiffen themselves around it, the slightest shock would suffice to throw it to one side. This is what happens in accidents where the weight of the body falls on the arm placed in a false position; the shoulder is dislocated; in other words, the articulation can no longer act, the little ball is driven out of its round hole, within which, its polished, shiny surface allowed it to move so easily.

No matter how loose the bandage of the capsule may be, you can readily imagine how this change of position must stretch it; so the only thing to be done is to send

off quickly for a surgeon to put all in its place again. Inflammation soon appears in the tortured ligaments, and setting a limb is a painful operation, from which I trust you may be preserved.

CHAPTER X.

THE ARMS AND LEGS—(*Continued.*)

You frequently hear of a dislocated shoulder ; dislocated elbows are by no means so common. You will understand the reason of this when you come to examine closely into the articulation of the elbow. The humerus at this point terminates in a hinge very similar to the pulley invented by man, and which has in all probability been suggested to him by Nature's own model. Take hold of your wrist, pressing the thumb against your forefinger, and pass the hand around the wrist ; it is exactly in this way that the bone of which you feel the point at the extremity of the elbow, and which is called the cubitus, comes and goes on the hinge of the humerus, which it seems to grasp with a kind of half-open hand.

You can imagine this being much more solid than a ball rolling in a hole or socket, especially as the hinge thus formed can only move in one direction, and so allows the arm no other movement than in a straight line, so as to raise the hand to the shoulder or to lower it. When you turn your elbow inward or outward it is not the elbow joint which contributes to these movements ; they proceed from the shoulder ; the lower bone is drawn along by the humerus in its evolutions without their respective positions varying a hairsbreadth.

The mechanism of this articulation can be examined with the utmost ease, as the bones at this point are simply covered with skin, and you can feel with your fingers

how they move without having to consult an ugly skeleton, as I constantly do that I may make no mistake.

First raise your hand to your shoulder, bending your elbow as much as possible. The hinge of the humerus is thus exposed, and if you place your finger on it you will soon feel it, when you extend the arm, driven away by the bone which glides on the hinge. Immediately above this hinge is a small hollow between the two protuberances which terminate the humerus, externally and internally. The bone of the elbow can move thus far, but on reaching the bottom of the hollow it strikes against it with its point, and suddenly stops, hence the impossibility of bending the arm backward, no matter how little. If you like to know what this impertinent point, which keeps the arm in its proper place is called, it is the olecranon or olecranon process. Persons, in speaking of accidents, sometimes make use of this word to show their knowledge ; you will now understand it if you hear it.

Here we are, my dear child, embarked in a regular course of anatomy, and if we intend to accomplish it and amuse ourselves by the way, we have no time to lose. Take your courage in both hands to follow me as best you can ; a little fatigue is an incentive to the mind as well as to the body, when it is not abused.

In the little experiment you have just made, this bone, which chased away your finger in moving on the humerus, did not seem very large ; nevertheless, if you touch the forearm below the elbow, you will find that it is a bone of considerable size. How does it happen that this large bone becomes all at once so small, just at the spot where it would seem to require all its force?

This is a problem requiring reflection, did I not save you the trouble. We have two bones which run parallel, the one to the other, throughout the length of the fore-

arm, and the space which separates them is so well filled by muscles that the two appear as one. Besides this, they are united by numerous ligaments, and a long covering of a particular kind, such as we shall presently see when speaking of the muscles, passes from one to the other, from the elbow to the wrist. You will easily understand mistakes being made when we are not acquainted with these facts, and, packed together as they are, they are apt to deceive young people who, left to themselves, would never discover the truth.

Two bones have been placed here for a good reason. Are you aware how very little strength you would have in your hand, if aided solely by its particular muscles, your hand turned upon your forearm, as your head turns upon your neck? The smallest effort would draw it to one side, and the best of cooks with the best intentions would be utterly incapable of tossing a pancake.

Happily the hand is not left to depend upon its own resources. It is firmly bound at the wrist to a bone, the radius, which directs it in all its movements, and which accompanies the ulna, or cubitus, the whole length of the forearm. The little round prominence close to the wrist, in a line from your little finger, is the extremity of the cubitus. Immediately beside it, commences the bone which supports the hand, which here spreads out and attaches itself, by a larger surface, to the wrist, and then terminates at the elbow in a sort of small crown, similar to the one at the lower extremity of the cubitus. In this manner, the two bones appear to be of the same dimensions at each end, the smaller extremity of the one leaning against the larger extremity of the other.

As you bend your arm, the movement is performed by the hinge of the cubitus, whilst its neighbor remains passive. When you turn your hand, it is the neighbor

which is the acting power, the cubitus in its turn being passive. The elbow and the hand have each its own particular agent, otherwise you could not turn your hand without moving the whole arm from the shoulder down, for the grooves at the elbow-joint are too firmly secured, one into the other, to admit of the smallest deviation to one side. Judge for yourself how easy it would be. Take hold of your arm above the wrist; hold it very tightly, so as to prevent the movement of the bone charged to aid the hand, and you will see what contortions of the shoulder are necessary in order to turn the palm of your hand outward.

I must now tell you the name of this bone, without which knitting a stocking would be a terrible affair. It is called the radius, from the Latin word, signifying ray, or spoke. If you see no connexion between the two, recollect that wheels have spokes. Again, wheels turn, and the radius turns the hand; but this, I think, is a little far-fetched. But as there are many words which signify nothing at all, we must not be too exacting as regards those which seem to have a meaning.

At length comes the hand. You are pretty well acquainted with it, I presume, and what I have to tell you about it will not be difficult. Like the arm it is divided into three parts—the carpus, the metacarpus, and the fingers.

The carpus is the scientific name for the wrist. It is composed of two rows of bones, each row consisting of four, closely pressed one against the other, and arranged so as to leave a passage in the intermediate space for the nerves and arteries of the hand, which traverse the wrist through tunnels, much in the same way as railways do mountains, where these precious organs are sheltered from all accidents. The veins, less delicate, pass nearer

the surface, when they separate, forming raised lines, clearly perceived—if not on your little hands, which have not yet been accustomed to work, they are plainly visible on the hands of those inured to manual labor. It is, in fact, on the back of the hand that the proverb which you, perhaps, have yet to learn, is best verified, "Who sees his veins, sees his pains." Believe me, if it is prettier to have tiny veins well hidden under the skin, it is more glorious to have them visible.

Each little bone in the wrist has a name; but it is useless to go on telling you of them one by one. The scaphoid, the trapezium, the os magnum or great bone, and the semi-lunar. All this cannot be very interesting. There is, however, one to which I wish to call your attention, for the curiosity and originality of the thing, for it seems to be a kind of superfluity, and appears to answer no purpose. This is the pisiforme, a word implying a bone in the shape of a pea, and it is in reality somewhat like a large dried pea.

Bend your hand forward. At the spot where it plays upon the head of the radius, you will easily ascertain this spot by pinching the joint with your thumb and first finger, the little ball of the pisiforme will glide under your finger with each movement of the hand. The pisiforme seems thrown to the extremity of the first row on the inner corner of the wrist, like an advanced sentinel who takes no share in the manœuvres of his battalion; and, in fact, this little bone plays no part in the movements executed by his big comrades.

As you may readily imagine, these movements are not extensive. The carpal bones are tightly compressed one against the other by a triple row of ligaments; a single synovial membrane, the folds of which bury themselves in the tiny hollows of their articulation, covers the whole.

Thus packed up, they can hardly move from their place. An almost imperceptible sliding takes place between the bones of each row. Between the two rows the movement is more sensible, for the joint uniting them has rounded surfaces, which permit of their being more readily displaced. Having mentioned the os magnum, or great bone, I may as well remark, that it is on this bone that the movements in the interior of the wrist are chiefly performed, and it sometimes happens that it is thrown out of its place ; as it is the only one of this band exposed to such an accident, I will tell you how to find the bone. Follow, as far as the wrist, the continuation of the bone which forms the middle finger, and of which we shall speak immediately, and you will light on the os magnum. It is the third in the second row, counting from the thumb, and its name sufficiently shows that it is the largest of the whole. It is rounded at the base, and fits easily into the scaphoid, the leader of the other row, which is hollowed in the form of a boat, a shape favorable to a balancing movement. Hence the harsh term scaphoid,—scapha being the Latin for a boat.

I see that we are becoming very learned. While on this subject, let us pass on to the metacarpus.

This is derived from the Greek, and, imposing as it sounds, is easily explained. It simply means that which is after, or which follows the carpus.

That part which is above the carpus, or the wrist, is the fleshy part of the hand from whence the fingers issue. You already know, I have no doubt, that the fingers have three phalanges, this is the name given to their division, besides you have only to look at your fingers. If you ever have courage, when visiting a museum, to examine the hand of a skeleton, you will find no trace of

what we call the palm; but you will see extraordinarily long fingers, with four instead of three phalanges, continuing in a straight line to the wrist. This fourth phalange is invisible during life, being lost in muscles, and enveloped in a covering of skin. It is called the metacarpus, and is simply a continuation of the fingers in the thickness of the hand. I caused you just now to trace the continuation of the middle finger; do the same with the others, and you will easily be convinced of the fact.

The metacarpal bones articulate with those of the second row of the carpal, into the hollows of which they fit easily, and as they are closely compressed at the base, it follows that their movements are very limited, being reduced to certain slight inflexions, which serve, however, in some instances, to increase the curvature of the palm. Try to hold some water in the hollow of your hand: the efforts you make to prevent its running over entirely proceed from the metacarpal bones, particularly from those which are continuations of the fore and little finger. These will be slightly raised on either side, so as to form a kind of barrier to retain the water which would otherwise escape. Yet you will not keep your hand long in this position without discomfort. The fatigue you experience will teach you how little the metacarpal bones care to change their usual position.

Among the five metacarpals there is one which forms an exception, and this is the thumb.

I have already spoken at some length of the thumb, and the service it renders us. It was with it, if I remember rightly, that we commenced our history of a Mouthful of Bread.

"Consider with respect your little thumb; it is to its three little bones covered over with a little flesh that man owes part of his physical superiority to other animals."

I could scarcely speak differently to a child who knew nothing about metacarpal bones. Now I can say to you, "it is to its three little bones," etc. In reality, the metacarpal bone of the thumb differs from its four neighbors, which are immovable columns, planted, as we may say, in the wrist, having scarcely any other duty than that of supporting the fingers. It is an alert and bustling agent, going and coming with perfect ease, moving its two phalanges from one finger to another, and all the honor of the meeting reverts to it by right, for, like the other phalanges, those of the thumb have no other movement than of flexion forward; all are alike unable to balance themselves upon their base. Here the base is short, thick-set, double the size of the others, as is necessary to a wrestler, destined to keep four antagonists in order at once. Instead of the articulating surface being square in form like the rest of the metacarpal bones, that of the thumb is slightly hollowed at the base, and rolls with ease on its supporter, the carpal bone, the end of which is rounded in the form of a saddle.

This is the trapezium, and now that gymnastics are so much in fashion, this name will not appear strange to you. On examining it narrowly, you will see that the exceptional play of the thumb proceeds in reality from this bone. Placed at the corner of his row, he leans forward like a corporal advancing his body to ascertain that his men are all in line. It is on this prolongation that the metacarpal of the thumb is seated, thus manœuvring on another line than his comrades, the immediate contact with whom would have paralysed all his movements. In short, it is to the advance of the trapezium carrying the thumb beyond its ranks, that this member owes its faculty, so precious a one for us, of being able to face all the other fingers. See how useful it is to know everything. There

are also in the world many important personages who cut a great figure, and whose names are in everybody's mouth, but if we knew all, we should often find that their great importance has its origin in some obscure corner, about which no one ever thinks or concerns himself, though in it might be found the secret of the position which they occupy.

Another consequence of this arrangement is, that in grasping anything tightly the efforts made by the fingers are directed to the metacarpus, which acts as a resting place for them, whilst the thumb seeks its point of support on the carpal, where its pivot is. The opposing resistance being thus distributed over two different places, the discomfort is lessened, and more force can be employed with less fatigue.

You now know almost all I have to say about the hand. For what can I teach you concerning your fingers ? you know their various uses too well to require further instruction. You see the movement of all the phalanges on themselves and on the metacarpal is the same ; the joints also are exactly alike. They are composed of two surfaces, rounded in front in the direction in which the finger bends with a small pad behind to prevent their bending backward. Their excessive mobility plainly shows that their hinges are well oiled, and in reality their synovial membranes present a very considerable development, worthy of being brought under the notice of young ladies who play the piano, for they have sometimes pieces given them to play, the correct execution of which exacts a terrible outlay of synovia.

Now one last bit of information about the phalanges. They are flat inside and rounded at the back. This seems a trifling remark, but nothing is unimportant in our machine. If the phalanges were round like a wand,

small objects would slip from our fingers; if they were lath-shaped they would be wanting in strength to resist violent efforts. Lath-shaped on the side which works, wand-shaped on the side which has nothing to do, they can seize objects firmly and solidly, and the reason for their particular conformation is so evident, that we find the metacarpal phalanges, which are not intended to take hold of objects, are simply wand-shaped, almost as round on the inner as on the outer surface.

If you take a glance at the arm you will see that its frame work is always spreading out from above downward, gaining in mobility what it loses in solidity. First a single bone, strong and massive, the humerus, which is, as it were, the trunk of this tree of a new species. Then the two branches, the ulna and the radius, each with its peculiar movement. Then the numerous subdivisions of the hand, first condensed in the carpus in a compact mass; next less constrained, but still kept in their place in the metacarpus, free at length and able to separate from one another, in the fingers which represent the expansion of the last branches.

I should like to know, could we condense the wood of all the branches and twigs of an oak, whether the amount would be the same as that contained in the trunk of the tree. If so, it is precisely what is observed in the case of the arm. We find the quantity of osseous or bony matter, in point of measurement, to be the same throughout the entire length of the arm, only in one part it is condensed in order to give solidity; in the other it is divided to increase its powers of movement. Weighed separately, the bones in the hand represent a fifth part of the total weight of the bones of the arm. Measure your hand, and you will find it will be a fifth the entire length of your arm; thus out of a piece of humerus of

this length, you would be able to cut the materials of the two rows of carpal bones and the nineteen phalanges of the five fingers, including the metacarpal bones. In like manner, if the phalanges and the small bones of the carpus could be melted like lead and cast in a mould, a piece of humerus the length of the hand would be produced. But this is an operation I would recommend no one to have recourse to; we should gain nothing by it.

CHAPTER XI.

THE ARMS AND LEGS—(*Continued.*)

I MUST have tired you greatly, my dear child, with this humerus, ulna, radius, carpus, metacarpus, and these other strange names I have been forced to bring before you, and I see with horror that in coming to the leg we must go over the same ground again. The history of the leg is but a repetition of that of the arm; but unfortunately such differences exist as to render it necessary to commence from the top and work downward. We must consequently again travel over the same road we did before. This is scarcely to be regretted, seeing that the real way to know a road well is to travel it twice. You will have here a remarkable example of the way in which nature adapts to different uses two organs constructed from the same elements, by introducing some special dispositions into each.

After closely examining the arm and leg side by side, we should almost be tempted to regard the former as a leg for taking hold of objects, and the latter as an arm intended to walk with, each one accommodating itself as much as possible to the peculiar work demanded of it. When young willows are planted with the head downward, the roots become branches and the branches roots, but such a change could never take place in the members of the human body, though the absence of one limb generally calls forth extra power on the part of the remain-

ing ones, in which statement the following story will bear me out :—

About fifteen years ago there lived a painter in Paris, who signed all his pictures "Ducornet, né sans bras," (born without arms). You need not rack your brain in order to discover how he could write ; his signature was made with his foot, and it was with it also, as you may suppose, that his paintings were all executed. That foot, however, had never trodden the ground. Deprived of half his limbs, this poor child's parents were obliged to choose his line of life for him, and they decided that his legs must be taught to supply the place of arms. Nothing more was necessary than to suppress the service they were destined to perform, in order, if possible, to constrain them to do the work for which nature had not provided suitable members. He was wheeled from one room to another, and when he went out, his father carried him on his back. I met them several times in Paris on the Pont des Arts, so I do not speak from hearsay ; and one day I had the good fortune to see this armless artist at work in his studio. Half reclining on a peculiarly shaped stool, he balanced himself with ease and firmness, grasped his maulstick and palette with the left great toe, and with the right used his brush with perfect facility. If his drawings were not masterpieces, we must not blame his foot ; for all painters possessed of hands do not produce *chefs-d'œuvre*. I cannot exactly tell you the anatomical changes this leg, called to other functions, had undergone in the short space of a man's life, not being sufficiently intimate to ask permission to examine the limbs ; but upon seeing them acting, I felt convinced they were no longer exactly like other men's legs. The toes, at least from what we could see of them, were tapered and elongated, imitating, as it were, fingers ;

and I know two bones, of which I must speak presently, that in other people occupy a considerable space at the heel, were in this instance, probably from want of exercise, undeveloped; and without having examined the foot, I dare almost venture to assert that these two bones nearly approached the modest proportions of the small bones of the wrist.* This story concluded, let us hasten to finish the history of these bones, for I imagine you are beginning to tire of it. Fortunately, we are nearly through with it.

The leg, I have said, is a repetition of the arm. You must then expect to find in it all you met with in the arm, only in a much more solid form.

First, I shall commence with the foundation on which it may be said to rest, and this we cannot expect to find movable as is the shoulder, scapula, which changes position with each movement of the arm. Mobility in this bone would render the gait undecided, and you would be exposed to falls when you attempted to run. Here the base is the hip-bone, which of course you must know; it rests on either side against the vertebral column, just at the point where this latter is most solid, and where the vertebræ are firmly joined together to form the massive sacrum, which I hope you have not yet forgotten. All is here immovable, and we have, as soldiers say, a solid base of operation.

In the thickness of the haunch we find two cavities similar to those we remarked, when speaking of the arm, as receiving the head of the humerus, but much

* Ducornet is not a solitary instance on record. Only recently the papers spoke of a young Belgian painter who was born without arms, Mr. Charles Feln. His paintings were last year exhibited in Paris with great success. When seated, he is said to use his feet with as much ease as other people do their hands.

deeper, so that the ball with which the femur terminates is almost completely embraced. Femur is the name given by the Latins to the thigh bone, the largest and heaviest of all the bones in the human body ; so large and so heavy that in taking up a femur one would imagine it to be a club. This is not an original idea. Travellers in uncivilized countries have more than once seen warriors with these natural clubs at their waists—weapons borrowed from death to produce death. This might be cited as one of man's most horrid inventions, for it evidently belongs to the infancy of the art of war ; we certainly tower far above these savage nations, with our newly-invented cannons of to-day.

The femur is not placed in direct line under the hollowed cavity of the hip. Its upper extremity is two or three inches further outward, but is joined to it by means of a sort of elbow which supports the terminating ball, and is called the neck of the femur.

If you wish to form an idea of the appearance of this joint, just imagine the wax model of a foot with a high instep, and all the toes rolled up like a ball. This comparison came into my mind whilst I was looking at the profile of the femur I have before me, turned upside down and resting on its upper extremity. In this position the neck of the femur pretty nearly represents what is called the instep, the ankle may also be found there, represented by a large projection, one of those apophyses of which I have so often spoken to you, to which one of the tendons is attached which puts the femur in movement. As to the heel ! here I own the resemblance is less striking. It is more hollowed and bent inward than we find in the actual heel. You must imagine the thumb to have dealt a blow in the wax so as visibly to lengthen it. This elongation forms another apophysis

large and flat, to which are attached certain tendons and muscles of the femur. Are you anxious to hear the name of these two apophyses? One answers for both; this is rather curious, but never mind. The ankle is called the small, and the heel the large trochanter. Here, however, my modicum of learning is at fault. I have searched in vain to discover the meaning of this word, and can nowhere find what it signifies. If you meet with any medical man able to tell you, I shall be very glad.

The femur increases in size as it approaches the knee, of which it occupies the whole width. Just feel, and you will see how large a projection it makes at this part, and if you move your leg whilst holding your knee tightly between your fingers, you will easily understand the play of the joint. There are two large bones of almost equal size, rolling one upon the other backward and forward, nothing interfering with this movement except the muscles of the thigh and of the calf of the leg. If the leg be bent too far, these bones strike against each other, without which the heel might be bent to touch the neck of the femur, as it naturally does in the leg of a skeleton which we can fold in two.

You remember the olecranon, that point of the ulna which at the elbow enters into a hollow in the humerus, and forms an invincible obstacle to the arm being thrown backward. Its counterpart is not found in the leg, yet the leg cannot be bent forward. There is an obstacle quite as serious as the bony point in the arm, nay, even more so, for it is less liable to be broken. Put your hand to the hollow of your knee—you will feel something like cords which you would almost mistake for bones when they stiffen. These are the tendons of which I was just speaking, and if you stretch your leg

forcibly, you will easily perceive that you must break them to make it go farther. Now the tendons are cords which do not break so easily as our hempen ones, and what is held by them is perfectly secured and may be trusted to. There are also very strong ligaments round the joint, which, when required, oppose all irregular movement, and the articulating surfaces of the two bones are arranged so as to prevent any gliding in an unnatural way, or from side to side.

I shall now pass on to the great curiosity of the knee—the patella, or knee-pan. The name is familiar to most persons, but few are acquainted with its history.

CHAPTER XII.

THE ARMS AND LEGS—(*Continued.*)

THE patella is not a bone like the other bones and we shall find in it some features entirely new. First, let us see how it is formed, and where it is placed.

It is a flat body almost oval in shape, and may be compared to a small flattened heart, but owing to the folds in which it is partly concealed, the shape is difficult to trace with the finger, especially at its lower part, where its apex is. It is situated in front of the knee joint, and follows the movement of the bone of the leg, against which it presses as the leg bends. This bone is of valuable assistance to us when we kneel, sustaining as it does, when in this position, the weight of the body, to which it furnishes a larger and more regular or uniform point of support than the bony projections situated beneath it could do. When you were quite little you had no patella—at your birth you had not even a trace of one. This is, by the way, one of the reasons why little children have so much difficulty in kneeling. The patella, it is true, makes its appearance like all the rest of the bones under a cartilaginous form, differing, as I shall explain, from other cartilages. I shall in passing give you some details which have not hitherto been comprised in the general description of the bones of a skeleton.

When we together examined the way in which the same blood nourishes so many different organs, assigning

to each exactly what it requires, I told you what happens to old people whose bones, laden with phosphate of lime, do not readily take up any more. The blood, not knowing what to do with the phosphate of lime it contains, deposits it as best it can among the muscles and on the arteries, until at length they become ossified, and death of the tissues ensues, their natural functions being destroyed.

What may here be considered an accident and the forerunner of death, is a natural process in the early stages of life among some of the articular ligaments and tendons. I must now, for once, anticipate a little, and tell you what is really meant by a tendon, after which I shall return to my subject.

The tendons are a species of whitish cord, by which muscles are terminated. They are attached to bones which they set in movement. In themselves inert, and devoid, like their fellows the ligaments, of all sensibility except when they are tormented, the tendons are in reality nothing but bundles of thread, or fibres, to use the scientific expression. They belong to what anatomists call the fibrous system, a word which is not new to you, since we spoke of fibrous capsules, and their duty is a passive one. The fibrous organs, which we find everywhere associated with the bones, seem to a certain extent to partake of the life of these latter, and form a group with them. Is sympathy of neighborhood the cause of this? This, I dare not assert; but certain it is, that both are greedy of the phosphate of lime, and readily absorb it as it passes, through sheer gluttony, as far as we can judge, for this material has nothing to do there, nothing at least that we can understand. The result of this is the appearance of a number of little bones smuggled in as it were, and which we all at once find taste-

fully lodged in the thickness of the fibres, and to which has been given the name sesamoids.

You remember the pisiforme in the wrist, so named from the resemblance it bears to a pea. The sesamoid bones take their name from their resemblance to the seeds of the sesamum indicum, a small grain of the form of an egg from which oil is extracted. I conclude from this that they must have nearly this shape; as they do not form a part of our bony structure, they are not to be seen in the skeleton. They appear in early life, and continue gradually increasing in proportion as years pass on. Some, however, like wisdom-teeth, only appear at twenty to thirty, or even forty years of age. Nothing is so capricious as the formation of the sesamoids. They never venture into the trunk, having a partiality for the articular ligaments of the fingers and toes. In the thumb, two are to be found in the ligament which attaches it to the metacarpus, and they are also found in the great toe, but for the other fingers and toes there is no rule. Sometimes they are only to be found in the articulations of the metacarpus, and sometimes we do not find them there; at other times they slip into the joints of the phalanges. It is all chance, like the shape of your nose or the color of your eyes. Chance, do I say? certainly there is a reason for this if we did but know it. Bichat having observed a great development of sesamoids on the feet of persons suffering from gout, modestly supposes that there may be some connexion between these little bony formations and the capricious malady which often puzzles the doctor as much as it causes suffering to the patient. Admitting this supposition, we should require to ascertain whether the development of the sesamoid produces gout, or whether gout produces the development of the sesamoids.

You do not guess, perhaps, why I have run away from my subject to give you this history of the sesamoids, of which no one ever speaks ; well, it is simply because the patella is nothing more than a sesamoid. Queen of the band, it is true, not only on account of its size, but for its known utility ; yet in spite of its notoriety, it is no less the offspring of the fibrous system, an illegitimate bone like its kindred. This explains a great anomaly, the only one you have as yet met with, of an articulation formed by the meeting or play of three bones all in movement at one time ; elsewhere we only find two in the formation of a simple joint. The cause of the anomaly is, that in the knee joint one of the three bones is a smuggled one, if I may be allowed to use this expression, which I have already employed. Those who arrange skeletons are obliged, on account of its importance, to preserve this bone in its proper place, but this can only be done by fixing it to the end of a metal band, for it is not attached to, nor does it form any part of, the bony fabric.

The knee is another place of predilection for these fantastic bones engendered by the fibrous tissues ; so partial are they to it as to forget their capricious humor, and are invariably found stationary at either side of the femur, and in the tendons passing behind in the hollow of the knee. Lastly, the patella never fails to display itself in the middle of the tendon of the quadriceps extensor of the thigh. Wait patiently, and I will explain this word.

I told you that the primitive cartilage of the patella is not formed like other cartilages. The fibres of the tendon which serve as its basis continue through the gelatinous tissue, and may easily be distinguished on the bone, fully formed, when its phosphate of lime is dis-

solved in acid, which, as you already know, can easily be done.

We have spent a long time over the patella, but I could not allow this opportunity to escape of teaching you a little mystery hidden in the depths of our organs, the existence of which few except the learned are aware of, and they only mention it without commenting upon its peculiarity.

Should you ever have imagined the patella had a different origin from other bones? Well known as it is, its celebrity should have brought the obscure class to which it belongs into notice. As yet so far from this being the case, you will see persons look surprised if you begin to talk of sesamoids. In the same way an upstart often makes a great stir in the world without any one inquiring into his origin, without the smallest ray of his success being reflected on the home of his family.

Enough of all this ; now let us return to the arms and legs.

After the knee comes the leg corresponding to the forearm. To be consistent we should say the foreleg, and call the part where the femur is, the leg, because we called its corresponding bone where the humerus is, the arm. But we will leave things as they are ; we should have too much to do if we found fault with all inconsistencies of speech, to say nothing of other inconsistencies.

I have already informed you that the leg, of course I mean the entire leg, is a repetition of the arm. You ought, therefore, to be prepared to expect the two corresponding bones of the forearm in this second part, and so you will find them ; but as the foot does not turn on itself, as the hand does, it would be unfortunate if it did

so, the bone which in the leg corresponds to the radius in the arm, on the inner side of the member, on a line with the great toe, this bone articulates at once with the femur above and with the foot below. It does all the work by itself, to be sure that it is properly done, and consequently monopolises all the nourishment which the blood distributes so equally between the two workers of the forearm. He who does not work should not eat. This is a law which ought to be easily understood by man, inasmuch as it is rigidly observed in his own system.

This monopolist, almost as massive as the femur, is called the tibia ; a pretty name, with an unpleasant association. Tibia is the Latin for a flute ; the existence of the word shows that if our early warriors used femurs as clubs, the flutes of ancient musicians were as certainly made of tibias. Jesters sometimes speak of a man's flutes, implying that his legs are only skin and bone. You will now understand the origin of the joke if ever you hear it.

The tibia's disinherited companion is called the fibula. I do not know whence derived, but that is of no consequence. The bone thus designated is only a long slender wand fixed solidly at its two extremities ; at one end to the first bone of the foot, and at the other to the tibia, by the side of which it seems to play the inglorious part assigned by the proverb to the fifth wheel of a carriage ; only the proverb is not fully realised here, since the fibula furnishes points of attachment for the muscles forming the calf of the leg, and thus it is so far useful. The fibula may, however be dispensed with, as in serious cases surgeons have been known to cut out the centre of it without the tibia being interrupted in its work. So if you ever hear people speak of any one walking with

a broken leg, you may be sure it is only the fibula which has been broken. A broken tibia prostrates a man as effectually as a broken spring obliges the carriage to which it belongs to discontinue its progress.

At this moment they are building me a beautiful class-room, in which it will be quite a pleasure to enact the professor. You can understand how interested I am in its progress, and that I often go and watch the carpenters at their work. I noticed how they set about uniting two beams; in the one they hollowed a deep groove, called a mortise, and in the other they cut a tenon; that is, a square projection exactly fitting into the mortise; joined in this way, the two beams formed but one, and so the leg is fastened on to the foot.

You know the two ankle bones; they are like two walls of the mortise, hollowed in the extremity of the tibia, which forms the inner ankle. The outer one is the extremity of the fibula, which is here invaluable to the tibia, and completes the closing of the mortise. Between the two bones of the ankle, a bone of the foot, the name of which I hope you will not forget, squares like a tenon. This bone is called astragalus. The square ornaments of cornices are called astragals, so you see we are still on the subject of architecture.

The astragalus placed immediately over the mortise of the tibia, between the walls of which it is held as if by pincers, receives all the weight of the body in a straight line, and transmits it to its comrade below, called the calcaneum; or, to give you the translation, the heel bone.

These two bones form the foundation which supports the entire edifice, and you will not be astonished to learn, that their size is considerably greater than that of the little bones of the carpus, the corresponding

bones in the hand. We now come to what we may call the carpus of the foot; but the name of the bones changes as well as their dimensions, and the carpus takes the name tarsus when applied to the foot.

The tarsus also has its two rows of bones closely packed together, but they do not go in sets of four, as at the wrist. The first row is composed of the astragalus and calcaneum, which two are certainly equal to the four carpal. The second row comprises five small bones, the names of which I shall not trouble you with. Next come the small columns of metatarsals, a faithful reproduction of the metacarpals, with the same number of phalanges as in the fingers; two for the large toe, and three for each of the others. But here the resemblance ceases. First there is this great difference, which you must be aware of: the great toe is placed on the same line as its small companions, with whom it cannot come in contact. Next these latter, having no work to perform, their phalanges, by virtue of that law that metes out food according to labor done, are so ill-fed that they are almost reduced to nothing. The blood reserves all its nourishment for the first row of the tarsus, which has so great a weight to bear; and for this reason: When speaking to you at the beginning of this chapter about the foot of the painter born without arms, where the duties of the arms had to be performed by the legs, I said that there were two bones in his feet very different in volume to those we find in the feet of other men. These two bones you now see were the astragalus and the calcaneum. Not put to any work, as they had not the weight of the body to support, the blood in all probability had given them half rations, in order to benefit the toes which worked the brush, and which, by dint of use, were positively elongated.

I hope you will not be offended at the advice I am going to give you. It is nice to have a neat little foot, and if every one went barefoot, the foot, like the nose, would quietly keep the shape given it by nature. Unhappily shoes are worn, so the shoe and not the foot is visible. The object then is to have a pretty little shoe; whence it follows that in choosing the envelope, we do not pay sufficient attention to what we are going to put within it. When the bones are pretty well developed, this little suffering we inflict on ourselves passes off when we get our feet into slippers. You will remember however, what I said about the cartilaginous condition of the bones in early youth, and how they do not become solid until later in life. The Chinese take advantage of this soft state of the bones to such an extent that they render the women incapable of walking. They actually envelop the feet of their infant female children in close-fitting iron boots, pushing back the still soft phalanges of the toes and metatarsus upon the tarsus, converting them into shrivelled stumps which are anything but pretty, at least to our taste. You must think of this if you should ever be tempted whilst young to wear too tight shoes. Never expose yourself for the sake of having the leather and prunella covering admired, to deform and destroy what it contains. In riches, in mind, in probity, in beauty, in all and everything, to be and to appear to be, are two rivals, which dispute the mastery in this world, and people are best judged according to the choice they make between the two.

One last observation on the shape of the foot before bidding adieu to the skeleton, whose name will, I imagine no longer awaken in you that disagreeable feeling of terror usual in ignorant people.

The calcaneum comes very low down behind, where it touches the ground; it then ascends to the height of the second row of bones, which itself is on an incline. The whole forms a species of arch, the summit of which is the highest part of the instep, just where the phalanges of the metatarsus begin. From this point the phalanges continue, the arch falling with a gentle slope toward the toes, and at this point of junction of the two, that is, where the phalanges and toes meet, a well-formed foot again touches the ground. The nerves, muscles, and blood-vessels of the sole of the foot are sheltered in the hollow of this arch; they thus escape the pressure of the weight of the body, a great advantage in long marches, where pressure might after a time irritate them and produce inflammation.

For this reason conscripts whose feet are too flat are refused by the military board of examination; it is assumed they cannot undergo the fatigues of a long march. The supposition is a reasonable one, but must not always be taken for granted, for I know a capital walker, who, in consequence of this defect, would never have been accepted in any regiment. Nature has resources unknown to us, and thanks to them, she is often enabled to counteract the apparent imperfections of her work.

For a stronger reason would I distrust the old saying that a flat foot betokens a dull mind; it would, indeed, be hard on some good people always to believe this to be the case. What a thing it would be if moral worth were measured by this rule. A great man's character would be at the mercy of his shoemaker!

But here let us take leave of this question, and proceed to discuss the muscles, which have long been awaiting their turn.

CHAPTER XIII.

THE MUSCLES.

When the shell of a house is completed the best half of the work is done; ask any mason and he will tell you that I am right. Do not regret the time we have spent over ours, nor any weariness it may have caused you, for, between ourselves, I could never have undertaken, during this somewhat monotonous journey through the human structure, to make it always amusing to you. I have done what I could to render it so, and have been reproached with taking too much trouble to make the road an easy one, under the belief that to study how to impart knowledge by saving children all possible trouble and hard work is calculated to do them more harm than good. In this my severe critic is right, I will not deny it, but even that need not affect me much. Whatever my efforts may have been, sufficient will always remain for you to do in order thoroughly to understand what I have undertaken to explain.

The best way I know of to make a child use its brain in good earnest, is to interest it; in other words, to amuse it. The most fatal enemy to mental exertion is ennui, for the simple reason that it benumbs the faculties of the mind. Certainly it is no fault of mine if I have not been more amusing while giving you this interminable history of the bones, seeing that the ghastly companion which I selected to render the subject more intelligible made me grave in spite of myself. There is

not much in a skeleton to induce mirth ; calmly as one may admire the very wonderful structure of the human frame, our natural dislike to the presence of death is apt to awe the strongest of us.

But here, with muscles we re-enter on life, and so we can prattle at our ease.

The muscles form a large battalion in the army of the artisans of the stomach. They compose what is called the flesh, that is to say, the principal part of the body, and their business is the same as that of the common people, who form the chief part of the social body. They undertake the heavy work. In the great buisness of walking, which the brain directs, they are the laborers, and the bones are only tools by means of which the muscles execute their work.

Hence the particular name of the locomotive given to each of these two divisions. Do not be alarmed at this expression, it simply means that which serves to move about. The railway locomotives will suffice, if necessary, to explain this to you.

I suppose you know enough of grammar to know the difference between an active and a passive verb. From this you will at once understand why our muscles, our laborers, are called active locomotive, and our bones, their tools, passive locomotive. The muscle moves the bone ; the bone is moved by the muscle. It is easy to ascertain when we walk which of the two bodies lays claim to the honor of the action.

We were just now speaking of the social body, I will therefore point out to you that it also has a double locomotive apparatus, the active and the passive ; the courageous élite which gives the impulse, the inert mass which receives it. Without inviting you later in life to join in political battles, which God forbid, let me advise

you in passing to be prepared before-hand to take your stand among the more honorable, that is the élite, of these two bodies.

You may shed a wholesome influence around you without making a great noise. Look at the muscles, does any one hear them? What progress, apparently impossible, might be accomplished without any visible effort were women only to play the part of muscles, and quietly help the world in its onward course!

Forgive me, my child, if I have forgotten what you are, by allowing myself to be carried away with the thought of what you may one day become. Meanwhile, as you are learning to imitate the conduct of the muscles and act as they do, let us quietly consider what a muscle really is and what it does.

I cannot do better than compare a muscle to a quantity of small skeins of thread compressed into packets, which are always subdividing until they become elementary threads, a thousand times finer than the finest hair on your head. Seen through a microscope, these threads, or rather fibres, to give them their proper name, look like a kind of rosary, the beads of which, placed at certain distances from one another, alternately shorten or lengthen the fibre, according as they approach each other or retain their original position.

Here, then we have a very simple piece of mechanism, have we not? nevertheless it suffices for every movement in the animal world, from the crawling of a worm to the leap of a race-horse, including even the gambols of young ladies of twelve years of age, during their hours of recreation. It is simply a contraction of the muscular fibre which lengthens out to contract again, and as it contracts draws to it what has to be displaced. Can you imagine anything more simple?

What is less easy to imagine is the why and the wherefore of this happy power of contraction, without which man and beast would be fixed to one spot, as if they were inert or inorganic bodies.

The why and the wherefore, do you ask? What a question! I have only to will it, and my arms and legs move of themselves. See whether it is not so; it was my will that directed it.

Assuredly, my little princess, things being as they are, you have but to will and you are obeyed. It is necessary, however, that you should know that if any accident befall certain nerves which proceed from the vertebral column on either side of the last vertebra of the neck, you may order your arms to move as much as you like, they will pay no attention to the command, and you will then see whether your will manages all. Know also, that if without touching your nerves some savant more curious than his fellows who are in the habit of experimenting on animals, should take it into his head, and have the power, to fill the arteries of your legs with water, no further orders you might give to the muscles in that part would be listened to; your will would be as nothing to them. By and by, when we come to the nerves, I shall enlarge on that mysterious power which slumbers in the muscles, ever ready to awaken at the command of the brain, when its auxiliaries are at their post, and which, at a given moment, brings together the beads of the muscular rosary, and then suddenly disappearing leaves them to themselves. At present it suffices to mention the fact, another time I will explain it as best I can.

Thus at the slightest movement agreeably to your wishes, you create a commotion along the whole line among a myriad of little beings, each of which suddenly embraces its neighbor. It is only in this way that you reign queen

in the kingdom of muscles, in compelling your subjects to love each other, and for my part, if I had to choose, I would desire no other royalty.

However, upon closer examination, this style of governing is somewhat inconvenient as regards action. The muscle acting only upon the part it is deputed to put in motion, by drawing its little friends closer to each other gives a power, acting in one direction—viz., that implied in shortening of the muscle, or contraction, which is the proper expression. You will now be puzzled to explain how accordion players can conform to the programme of their music. How can they both pull and push, the one action being the reverse of the other, if the muscles are only capable of contraction? I must relieve you of your perplexity, indeed I am obliged to do so, for this is just a case in point with the peculiar arrangement found in the entire muscular kingdom.

Europeans when they arrive in India, are very much put about unless they be disposed to wait upon themselves. In our country a small family may manage very well with one servant, but in India, each servant has his own department, one cooks, another sweeps, another brushes clothes, a fourth washes dishes, and so on; if the master smokes, he requires a servant to carry his pipe, and on no account would he carry anything else.

This is exactly the case with the muscles; there is no occasion to inquire how they would succeed with double work; they are only upper servants undertaking but one duty. Do you wish to bend your leg? a special muscle at once draws the tibia toward it and carries it backward. Do you wish to straighten your leg? another muscle has immediate orders to bring the tibia to the front by drawing it toward itself. The process is exactly the same only applied in a contrary direction.

Imagine me standing in front of you, face to face, with some one else at your back, each of us laying a hand on your shoulder. I oblige you to bend forward, by pulling you toward me, but I need not push you back to your place to make you stand erect, it devolves upon the other hand to accomplish this by pulling you toward it. Our bones then are placed between rival powers, antagonists, according to the term here given, which oblige them to move each in its turn. According to this arrangement, when one muscle works, another rests ; a fortunate circumstance for us, as they are short-winded workmen, and require to rest every moment. If the same muscles were constantly in motion whilst we are walking, it would be impossible to take fifty steps in succession. Without entering upon a series of explanations, I will only ask you to hold your leg firmly extended six inches from the ground. You can sit down if you desire to be more at your ease. This does not appear difficult, but as in this posture the muscles cannot relieve one another, I am quite sure that in less than five minutes you will be tired enough.

These are the extensors of the leg mentioned during our study of the patella, and they will beg to be spared the little experiment I have just proposed to you. Their duty sufficiently explains their name, which is to stretch or extend the leg.

Their antagonists enabling it to bend are called flexors, and to these muscles we are in reality indebted for the power of kneeling.

The muscles are classed in categories named in accordance with their functions. There are, for instance, the levators, which raise ; the depressors, which draw downward, two antagonistic classes, as you can easily imagine ; the rotators, (*rota*, a wheel,) which turn ; the

abductors, (*ducere ab*,) to move from; the adductor, (*ducere ad*,) to draw inward, and others besides; and to each individual muscle of each different class a special name has been given. There are extensors, flexors, etc., on all sides, so it was necessary to name them in order to recognise them. I leave you to think what would become of us if we were to review the muscles as we did the bones.

We must follow the example of visitors to a ship-building yard, who inform themselves minutely of whatever concerns the tools, without inquiring the names of the workmen. The individual on whom the duty of explaining the various departments devolves simply observes to the visitors, "These are the fitters," "those the turners," etc., etc., particularising the work assigned to the men, irrespective of their being called James, Peter, John, etc., information only regarding the work done by them being of service to the inquirers.

You will readily agree it was not wrong in this instance to think less of the men than of the instruments they were using. In the same way, then, do not think because I do not enter into details as to the names of the different muscles, that they rank below the bones. They are organs of a very superior order, but are so numerous, what else can I do? Besides, a workman's history is in his work, so interesting a one that he seeks no other. With those persons who do nothing, it is necessary to talk about themselves, seeing there is nothing else to talk about.

CHAPTER XIV.

THE MUSCLES—(*Continued.*)

THERE are some people so exclusive that they are averse to anything like contact with those in the lower ranks of life. When they require the services of the latter, they give their orders through the medium of other parties, who, though belonging to the lower orders of society, manage to insinuate themselves into the fashionable world, which they govern by transacting its affairs.

The muscles belong to this class of exclusives. Between their restless flesh and the inert phosphate of the bones, the bond of connexion is established through the medium of a third class of agents, who fraternise on the one hand with the bony masses, and on the other slip in among the bands of muscular fibres, of which they are at once the protectors and the agents.

These intermediate agents are the fibrous organs.

To each muscular fibre a fibre of an inferior kind is attached, which is incapable either of contraction or extension, and which, intermingling with the neighboring fibres of the same class, forms a kind of tough web, enveloping the interior divisions of the muscle, as well as the muscle itself. This web is called the aponeurosis. *Neuron* is the Greek for nerve. This word is still preserved in the Greek, I don't know why; it remains there as the representative of an old error at which we have already laughed once.

You will not have forgotten the little dictionary I told you of the other day, which defined *tirant* as *yellow nerve*. It was only the echo of the belief which catalogued, once upon a time, all the fibrous organs in the category of nerves, and it is, thanks to this belief, now discredited, that we still give the name of *nerves of beef* to the tresses which are found among the tendons of beef.

The aponeuroses, though they have nothing in common with the nerves, are nevertheless exceedingly useful to the muscles, whose fibres they keep in their proper places. Without these strict guardians, the little bundles of fibres of which the muscle is formed would become deranged at each contraction, just as the threads of a skein would which you might try to wind without its being held. But profit does not always result from being too well guarded. A government in which the power is too absolute becomes wearisome to a people fired by the love of liberty; and so the aponeuroses, which never yield, cruelly oppress the muscles when the latter become inflamed.

Instances of this kind are often met with in temporary hospitals organised for the wounded after an engagement. Nature only knows one way of repairing the injury man does to his fellow: this is by letting the blood flow in quantity through the severed flesh and gun-shot wounds, and allowing it to accumulate in the injured parts. This valuable steward, the blood, has plenty to do at these times. To rebuild the breaches, to clear away the materials so brutally destroyed, to cause to re-enter into the torrent of the circulation, as we say, the liquids which, escaping from their broken or ruptured canals, have spread themselves among the tissues where they cause irritation—all this is no ordinary work, and whilst it lasts requires the repairing

agent to bring all his powers to bear in the theatre of action. The muscle gorged with blood endeavors to swell, but the inflexible aponeurosis imprisons it on all sides, and stops it in its attempt. It is the same as with these little feet of which we spoke, when compressed into a still smaller shoe, only in the former case the poor wounded man's sufferings soon become so excruciating that relief can only be obtained by cutting the web. This is called incising or unbridling a wound. In fact, the only remedy is to slacken the rein for the fiery muscles, which eagerly cry out for more space. The alternative is rather violent, and astonished me the first time I saw it resorted to; but if such means were not had recourse to, gangrene would appear in the muscle—I will explain why another time—and death of the entire body would be the result of the obstinacy of a stupid piece of web, which could not accommodate itself to circumstances.

You must, however, hear both sides. This inflexibility of the intermedial fibre, so dangerous in extreme cases, has also its valuable properties. The fibrous organ not only prevents the muscle from straying, but is further commissioned, and this is its main function, to compel it to obey its orders. Now, if it were elastic, if it could elongate itself under the traction of the muscle, it would expend a considerable amount of its strength, which would in no way assist the movement, and the bone would but half obey the injunctions of its lord and master. The inexorable rigidity of this intermediate agent obliges the bone to yield in exact proportion to the contraction of the muscle. So we sometimes find troublesome servants are in the end the most useful to us.

Now, let us consider by what authority this agent of

the muscle exercises control over this rude vassal, whom he causes to march at his bidding.

You know all about the periosteum, the membrane covering the bones, and incorporating itself with them on such good terms that, as we have already observed, it furnishes them with a series of external layers as fast as the old ones disappear from the interior. The periosteum is also a fibrous organ, and so when the fibrous organ of the muscle reaches the bone, it finds a companion ready to bid it welcome; the two unite their fibres at the point of attachment, and owing to this union of their servants, if I may be excused the term, muscle and bone are at last connected in spite of their diverse natures.

These attachments are effected in several ways. Sometimes by a web, an aponeurosis lodging itself in its entire breadth within a groove of the bone. Sometimes the fibres disperse, and fix themselves singly on the periosteum, like threads of velvet upon the woof; and sometimes they all unite in one bundle, forming long cords, which we already know, called tendons.

The muscles presiding over the chief movements of the limbs are generally attached to the aponeuroses above, and by tendons below, and I am about to tell you why.

I need not explain to you, that in order to draw anything toward you, you must yourself have a foundation to rest upon. The general foundation of the body is the vertebral column which forms the centre, and the different parts of the members of the body leaning one against the other, proceeding from the extremities toward the trunk; it follows that the muscles moving the hand are fixed to the forearm, those moving the forearm are fixed to the arm, those moving the arm are planted

in the shoulder-bone. It is quite natural, then, that the attachments should become larger at the points where they rest, for the larger the foundation is, the more solid it naturally becomes.

Watch your brother at his games, see how he exerts his strength in drawing his companion toward him. The boy resists with all his might. Your brother separates his legs to give him a firmer purchase, presses his heels into the ground as he throws himself back. The legs support the trunk, which maintains the arms, and these latter stretch themselves forward to their full extent, drawing toward the trunk the boy to whom they, the arms, are attached, by the hands. In this position your brother's body can give you an exact idea of what takes place in each of his muscles. Imagine the trunk to be a muscle, the extended legs will represent the expansion of the aponeurosis which fixes the muscle to its basis, and the arms will be the tendons by means of which it draws the bone placed under its control to itself. But all this will fail to give you a clear insight into the world of muscles. To know a country we must have visited it. I am going to show you this one, by fully describing a muscle with everything belonging to it. You can understand I do not mean to choose the first comer, by way of doing him honor. That which I select is one of the most active of the artisans of your stomach, working for you each time your hand approaches your mouth, and is called the flexor of the radius; a muscle whose name is rather popular, if not among young ladies, at least among men who have any pretensions to strength, —it is called the biceps.

CHAPTER XV.

THE MUSCLES—(*Continued.*)

Biceps in Latin means with two heads ; the term is applied to a mountain whose summit is fork-shaped. The famous Mount Parnassus, sacred to Apollo and the Muses, is so shaped. There is a verse somewhere, either in Horace or Ovid, that occurs to my recollection, in which it is styled "the two-headed mountain." It is no small honor that the flexor of the radius should bear the name of so celebrated a mountain.

Our biceps is also fork-shaped at its summit, and hence its name ; its position is at the inner side of the arm, that part touching your chest when you press your elbow against your body, but its entire course is difficult to trace with the finger.

How astonished any one is upon going for the first time on board ship, at the sailors being able to distinguish the different parts of the rigging among the multitude of cords interlaced in all directions, each of which corresponds to a special movement of the yards and sails.

Suppose our muscles were unable at the first summons from the will to act of themselves, if, like the sailors, we had to select the rope corresponding to each movement we wish to execute, how very complicated the work would be! Not only are our muscles interlaced like the cords of a ship, but their fibres become so

entangled and amalgamated that they appear at certain points to be only one, while a little farther on they reappear in an isolated shape, so that we do not know at all times whether we have to do with two muscles or only with a single one.

This is the case with the biceps.

Its neighbor is an adductor of the humerus. You recollect the word adductor when I enumerated some of the muscles ; it signifies that which draws inward. This adductor, as well as the biceps, is planted on an apophysis of the scapula, by means of an aponeurosis common to both.

There is a nice collection of scientific words, and I am delighted to be able to make use of them in addressing you. Certain it is that the aponeurosis in question envelops the two muscles at once by means of its prolongation, the fibres of which at the outset are found in close contact, and seem to form but one. Then this covering divides right and left, and the bundle of fibres belonging to the biceps muscle being set at liberty goes off to rejoin the body of the muscle, where it disappears in the vicinity of the upper third of the humerus.

I told you the biceps has two heads. This one of which we have just been speaking is its first and least important one—the short head, as anatomists call it. The other the long head, descends from a swelling on the upper edge of the hollow in which the head of the humerus is lodged. It is attached there by a very long tendon, which is distorted in a ligamentous form on the head of the humerus, and traverses the articulation concealed in a fold of synovial membrane, as if in a sheath ; leaving its synovial sheath, the tendon becomes enlarged, and insensibly changes into a thick round muscular bundle, it first runs along the side of the short head, then opposes it, and

at last absorbs it, as the Rhone absorbs the Saone at Lyons.

It is at the point of junction of these two muscles at their confluence, if we carry out the comparison, that the muscle is the thickest, it gradually decreases toward the elbow joint, and as it approaches the joint, the muscle may be seen to degenerate into a tendon, large at first, then very thin till it appears lost in the muscular fibres; whence speedily disengaging itself, it attaches itself under the form of a compact cord to a tuberosity of the radius.

Tuberosity is the correct word here, and I make a point of using it, because explaining its meaning gives me an opportunity of unfolding some of the principal conditions which preside over the action of the muscles on the bones.

Tuberosity means a small knob, hence the term tuber applied to potatoes which are really knobs growing on the root of the plant. It is not without reason that the lower tendon of the biceps attaches itself to the tuberosity of the radius, neither is it without reason that the upper tendon fixes itself on the little prominence, and its fellow the aponeurosis of the short head on an apophysis, which is a tuberosity also if you remember.

Lay a small plank on the ground and nail a cord along it, lie down flat on the ground, place your two feet against the end of the plank, try to draw it toward you so as to exercise traction on the beam from above, instead of horizontally; in addition to this, you may attach the cord to the top of a peg planted in the plank, and if you employ these two means at once, the operation will no longer be a difficult one.

You will thus have accomplished exactly what the flexor of the radius does when it attaches itself to the

ridge on the bone which is its fulcrum ; in order to raise it a little, it fastens its cord to the summit of the little knob of the radius. These various irregularities observable on the surface of the bones—and which I have hitherto passed unnoticed lest I should tire you with details of secondary importance—these rough parts or ridges invariably serve as points of attachment to the muscles ; this is so truly their use that they are constantly found in size proportioned to the strength of the muscles which cling to them.

On looking at the biceps of a wrestler whether tall or short, you may be sure the tuberosity which receives the tendon forms a much larger projection on the radius than it does in an individual of the same size, whose muscles are slender and without energy. In the same way, by the size of the projection on the bone, you may judge of the power of the muscle attached to it.

To give you one of the most striking illustrations of this : the anatomist is in a position to state without having seen the animal, by simply examining a fragment of its jaw, that it was originally possessed of formidable muscles, and that it belonged to the class carnivora.

Besides, the projections of which we have been speaking would be too small, in many instances, to raise the muscles, if the bone requiring to be set in motion were placed horizontally to that acting as its fulcrum ; it is the story of yourself and the plank I just now proposed.

Nature has provided for this in another way. Here, for instance, the humerus and radius are each slightly curved inward, forming a kind of arch, the two ends of which do not meet in a straight line. This double curve is also found in the thigh and leg bones, but I have postponed mentioning this peculiarity until I could tell the reason of it.

Here, my dear child, you see how much there is to admire in the study of nature, how as you advance the way becomes easier ; what at one time seemed difficult grows more intelligible each step you take. In nature nothing is left to chance ; no apparent caprice but is accounted for in due time. Not a molecule of matter has been placed without an intelligent design ; even when she appears, as in the case of the sesamoids, to have reserved to herself the right of indulging her fancy, there is an object in view. These mysterious formations on the tendons aid them in their way in exercising traction on the bones, in raising the fibres of these tendons above the horizontal line. The sesamoid is to the tendon what the peg is to the plank.

I could not have explained all this to you before telling you of the facts to which they refer. What a pity we do not know everything ; how clear-sighted we should then be !

To return to the biceps ; I should much like to know whether when I began my description of it, a very natural thought suggested itself to your mind. We saw two bundles of muscles, undistinguishable at their source, hidden as they were by the aponeuorosis which encloses them in a single packet, yet each has its particular destination, and it is not the same movement they are called upon to execute. How then, in the performance of their respective functions, can they avoid impeding each other's progress ?

The question would be puzzling were it not customary with these bundles to work together, so that the two movements are almost always performed by a simultaneous contraction. Let the adductor of the humerus be brought into play so as to draw the arm toward the chest, you will see that, quite naturally and uninten-

tionally on your part, the forearm will bend on the arm, by an instinctive contraction of the biceps. If, however, owing to any intervention of the will, you raise your arm up to your chest, at the same time keeping your forearm well stretched out, the inconvenience and stiffness of this intentional movement will soon warn you that you are acting contrary to rule. Again, try to draw a rather heavy object toward you,—in turning your arm outward, that is to say—by contracting the fibres of the biceps and relaxing those of its twin, your power will be far less than if you were to allow the two muscles to work in concert, and let the arm raise itself to the chest whilst the forearm bends on the arm.

In order to be exact, I ought to mention that there are other muscles at the shoulder and upper part of the chest, which are attached to the humerus, and are ordinary auxiliaries in the various movements of which I have just spoken. The auxiliaries assisting or refusing their aid, according as these movements take place or not, in the sense of their contractions. The muscles I have represented as upper servants, willing only to undertake one duty at a time. Particular as they may be, they are no more able than our servants are to act alone. Throughout the body they constantly require a helping hand. There are among them, as in every organised society, certain recognised mutual laws, from the observance of which they cannot escape without weakening the general effort; of this we have an example at every step.

Set a strong man to do some hard work to which he has not been accustomed, and his strength will appear to forsake him; and he who could follow a plough the whole day without fatigue would, if unaccustomed to work with the oar, become useless after an hour's rowing. The

body, unaccustomed to new duties given it to perform, cannot at first take the position necessary to harmonise the play of the muscles, which should move in concert; instead of giving that mutual support in which lies the secret of their strength, they betray each other, and even at times interfere with each other's action, and strength is of no avail. It is like a team in which each horse pulls in a different direction; the strength of the animals is exhausted, but the wagon stands still.

CHAPTER XVI.

THE MUSCLES—(*Continued.*)

Having selected the biceps as the type in our study of the muscles, I shall refer to it once more.

I know that your eldest brother prides himself upon his strength, and certainly his muscles are tolerably firm. Feel his arm as it hangs down by his side, your fingers sink into it without any effort; but ask him to double his arm vigorously, then put your finger once more upon his biceps, which has now become energetically contracted in order to draw the forearm toward him, and you will encounter a tolerably hard body on which your finger makes no impression.

How do you account for this resistance, which hitherto unfelt now suddenly appears?

This, my dear child, is an example of the power of concord between members of the same body. Union is strength; such is the case among mankind as well as elsewhere. So long as your brother's arm hung quietly at his side the biceps was relaxed, the beads of the millions of little rosaries of which it is composed, instead of being attracted toward each other, were floating about so that you could easily displace them with your finger. At your request a mysterious act of volition brought a power of attraction into play, which suddenly affected all these unconcerned beads, precipitating them against each other, and, so long as this power lasts, they deter-

minedly oppose every attempt to displace them; a disseminated powerless crowd of particles suddenly gathers itself into a compact and united group, presenting a mass not easily overcome. You never for a moment imagine that nations could derive a lesson from this biceps muscle, whose resisting power disappears as soon as the mutual attraction of the muscular atoms vanishes; but we are verging on politics with our biceps, and I may soon have to ask, Where are politics to end?

To return to the history of the human body, it is desirable you should know that this sudden hardness of the muscle, when it is contracted, has incomparably more important duties to perform than opposing the pressure of the finger. It is an invaluable safeguard to our joints, and what is of still more importance to us, it prevents our mutilating ourselves upon every little exertion.

The ligaments surrounding our joints are very strong, nevertheless they would not always suffice to retain the bones in their respective places if the muscles, stiffening with every movement, did not second them, and form, as it were, another line of defence. I spoke to you of this during our study of the shoulder, when I explained that the articular capsule allows so much liberty to the head of the humerus that, but for the rigidity of the adjoining muscles, the bone would escape from its socket. It is at this part that the muscles are guardians, *par excellence*, of order around the articulations, but though not quite so apparent elsewhere they play a part not less important, and when a limb is paralysed, that is to say, when its muscles have lost the faculty of becoming hard on contraction, dislocation takes place much more easily.

Once let death, that universal paralysis, appear, and the artificial power which each movement developed in the muscle departs never more to return, and the muscle is

thus compelled to deliver up the secret of its real weakness.

Detach a muscle from a dead body, and to its tendon fasten a weight; it will not require a very heavy weight to tear the muscle, though the tendon, still intact, is sufficiently strong to support a much greater strain. Now during life the case is the very reverse.* No matter how violent the effort, a broken muscle is an unheard-of thing, and whilst muscles remain whole, tendons are sometimes ruptured. If people take extraordinary or sudden leaps they are liable to break the tendo-achilles, which is the tendon behind the foot, at the extremity of the calcaneum. If you wish to know the origin of the name tendo-achilles, you must take a peep into mythology.†

I think you must now be sufficiently acquainted with your muscles, which assuredly are by no means the least useful of your organs, since without their aid you would be unable to walk a step, to write a single word, or what would be still more deplorable, you would not have the power to kiss your mother.

You think, perhaps, that I am joking; far from it, I am quite serious. Your lips are muscles which alternately stiffen and relax, as you close your mouth in order to re-open it, and your mother's cheeks which are also muscles, have their part to perform. If there were

* "Fibres of muscles ruptured are met with, though rupture of an entire muscle is certainly not known."—*Note of Translator.*

† The goddess Thetis dipped her son Achilles in the river Styx, which rendered him invulnerable in every part except the heel, by which she held him. On the capture of Troy, Polyxena was promised to Achilles as his wife, but while he stood before the altar of Apollo, her brother Paris wounded him mortally with an arrow in his vulnerable heel, where the tendon joins the calcaneum.

no muscles to act this double part, you might say farewell to kisses.

There is, above all, a certain labial or lip muscle, that takes a prominent part in the various movements of your mouth, about which I must say a word or two. It would be a great pity, whilst we are on this subject, to omit telling you of this useful handmaid in our little kingdom.

You have seen a young lady's work-bag, and know how it opens and shuts. A runner is made all around near the opening at the top, and a double string passed through. If you wish to close the bag, you draw the two strings outward holding them at the two extremities, the runner gathers up into a little packet of folds with the movement, and nothing can fall out.

If you wish to open the bag, you take hold of the two sides of the runner, and gradually pull them apart, which leaves the opening free. All this you must often have seen, and you, no doubt, have been in the habit of making work-bags for yourself, or bags for your brother's marbles.

Now just imagine to yourself a runner that shuts and opens of its own free will without the aid of any string; such a runner is the labial muscle. Its fibres are arranged in circles all around the opening of the mouth, and this opening either shrinks or enlarges according as the fibres are contracted or relaxed. Pucker up your lips for a moment and look at yourself in the mirror; you will see your lips are drawn together into a heap, forming a quantity of tiny folds similar to those caused by the runners on the bag. This is the position they assume of themselves when you suck barley-sugar, or when you fill your glass too full to lift it to your mouth, and are obliged to stoop down and drink from above.

This delightful little labial, the barley-sugar and kissing-muscles, does not, as you see, act in the same way as the muscles of which we have hitherto spoken. It has no bones to move, and its contractions have no other object than to make it close upon itself, and for this reason it can hardly be classed with its companions in the arms and legs. Placed like an advanced guard, at the entrance of the digestive tube, this muscle claims some connexion with it, and to a certain extent participates in the nature of these internal muscles, like the stomach, the heart, and the diaphragm, whose occupation is not dependent on the will, and which only contract for their own pleasure, and take care never to over-exert themselves. These muscles always have fibres arranged in circles, or rather crossing each other in every direction, whilst the fibres of the other muscles are arranged in straight parallel lines ; and though we have not terminated our study of of them, I am not sorry to have had this opportunity of teaching you wherein the tissue of these proud republicans differs from that of your very humble subjects. The humble subjects are those obedient to the will, as, for example, those of the arms and legs, etc., etc.

As to the labial muscle, if it does not always wait to help you to prattle until you have given it positive orders to do so, it is nevertheless, at your disposition. It is owing to this peculiarity, namely, its apparent independence of the will, that it is associated with the little kingdom, on the limits of which it stands. It is a muscle of transition which passes from one country to another, and the two lives I mentioned to you at the beginning of our study, the life of nutrition and the life of relation, each lays claim to it. Its position resembles that of the tongue, which is a muscle of nutrition when we swallow, and a muscle of relation when we speak ; but in the one case,

as well as in the other, it is under the control of the will. Of course I do not include those who have never learned to command their tongue ; only that the tongue, penetrating farther within the confines of the interior of the republic, resembles more closely what is to be found there. Fatigue is unknown to it, at least mine has never yet made any complaint ; how has it been with you ?

This reminds me that I have still something to say to you about the muscles before we leave them. A short time since I called your attention to that peculiar sensibility of the ligaments, which allows them to be pierced, cut, or burned, without crying out for help,—that is to say, without their awakening in us any feeling of pain, yet which energetically protest immediately they are pulled or twisted. The muscles differ from them in some degree, and are sensible to pain when they are cut. If you cut your hand with a knife, the pain proceeds less from the section of the muscles than from the contact with the air inflaming them and impregnating the blood with oxygen, neither more nor less than if it had encountered the blood in the lungs. In proof of this, certain operations are performed in which muscles are divided almost without causing pain, by means of a fine instrument delicately introduced beneath the skin. Surgeons call this operation sub-cutaneous section.

Nevertheless, these brave attendants who transport us where we wish to go, are far from being devoid of feeling. Each organ in its own way gives us notice if all be not going on smoothly ; the over-exerted muscles make it known by an especial pain, if I may so term it, by fatigue, and however modest their demand may be at first, if their cry remains unheeded, they at length

become imperious. A little fatigue is of no consequence, whilst excessive and protracted fatigue may become so unbearable as to render death a welcome release. Instances are on record of individuals having been so worn out on a march that they have chosen to lie down and await death, rather than continue the struggle.

I hope, my dear little girl, that you may never experience a fatigue from which death would be a release. Yet though we be not exposed to excessive lassitude, we are continually liable to experience fatigue; let me, therefore, give you some advice on this subject.

Do you recollect that walk in the wood a few days ago, when for a short time you had lost yourself, instead of walking you dragged your body along, making all kinds of dreadful lamentations. No sooner had you found the right track, and caught sight of the house, than you jumped for joy, your fatigue vanished, and by the time you reached the garden-gate you were ready to set off running. Here, it strikes me, is a useful lesson for you. Muscles are like naughty children, who cease crying when they see you take no notice of them. The more you sympathise in their little annoyances, the more compassion you show for any little accident that befalls them, the more disconsolate they become, and nothing so increases real fatigue as to repeat constantly, "How tired I am!" Spoiled children, who have never been exercised in the school of obedience, are incapable of the smallest effort. On the same principle, let me beg you to bear in mind, that if you wish your muscles to obey you later in life, when you will seriously require their help, you must not treat them now like spoiled children.

As regards fatigue, I am afraid I may have tired you in dwelling so long upon the bones and muscles; they

are at last concluded, thank God. I am now about to show you how the machine which we have been so carefully examining, piece by piece, works as a whole. I have been a little tedious perhaps, but the subject concerns you very deeply.

CHAPTER XVII.

ATTITUDES.

I AM about to speak to you of the different attitudes; in other words, the various positions the body is capable of assuming without any change of place.

For some time we have been playing the part of the learned in inquiring, as anatomists must do, into the history of the bones and muscles that are concealed below the skin, and which to be properly understood must be studied. We are now competent to converse on these matters without calling in the aid of books. Every person knows what it is to stand erect, to sit, to kneel, to lie down; and these are things as familiar to you as they are to the professors in the school of medicine; still they deserve our attention, inasmuch as the fact of a little girl being able to sit erect is not sufficient, she should also be able to explain why she does so. Your little dog stands more firmly on his paws than you on your legs, yet he is unable to give any reason for his ability to do so. We shall soon master the mystery, however, and be greatly in advance of him on this subject.

When I say, soon, I perhaps speak a little at random. Have you any idea what turn our conversation must now take by way of commencement? Well, I am going to speak of that same law which causes the earth to move round the sun, and which ever since the creation has regulated the course of the stars through the immen-

sity of space. The subject is no trifling one, you see, and when a little girl, by her inattention, gets a tumble, she should be able, as she rubs her injured nose, to console herself with the thought, that a power governing the world and exacting obedience from the stars is the cause of her fall ; only that the stars never fall, because they always do as they are told to do.

Man is very proud of being the only creature of the animal kingdom that can maintain an erect posture, his face raised heavenward. This is a legitimate pride ; and would to God that it accompanied him on all occasions, in his actions as well as in his gait. But to all honors penalties are attached, and those who attain to the dignity of walking erect require to look out, and learn how to maintain their equilibrium by attending cautiously to their centre of gravity, liable as it is, at every moment, to be impelled forward from the basis on which it rests.

A mysterious, universal, unfailing law exists, attracting all bodies, large and small, toward each other : the book lying there toward you, you and it toward the ground, the ground toward the sun, and the sun toward the unknown centre around which it gravitates. This explains the origin of the word to you, and the idea it recalls. The great Sir Isaac Newton, who first ascertained this power, gave it the name of gravitation, from the Latin word, gravis, meaning heavy ; it is also called attraction, weight, gravity, according to the different aspects under which it is considered ; but all these terms imply the same thing, viz., the power inclining various bodies toward each other, the love they have one for the other thus affording a fine example to lovers.

If I am able some day to find time to write you a book on astronomy, I shall have a great deal to tell you

regarding this universal law of attraction, which is the fundamental basis of our astronomical system. To-day I shall content myself by informing you, that the larger the body and the nearer it is, the more considerable is its power of attraction. Naturally, when two bodies attract a third, and each one acts for itself, the more powerful body will be the conqueror.

Now, on the other hand, this book, this chair, that cupboard, that house, yon distant hill, each one of these bodies vies with the rest in attracting you toward itself; but as these objects are as nothing compared with the gigantic globe upon which we live, or the earth, which in its turn attracts us toward itself, so all these minor attractions disappear before the larger one.

On the other hand, the sun, the moon, and all the stars that are visible by night in the sky, not to mention millions of invisible ones; all these stars, in obedience to the law of attraction, call you, my dear child, toward them, unconscious though you be of the honor they confer upon you.

To take as example one of these bodies; the sun, for instance, is one million four hundred thousand times larger than our earth, which appears but an imperceptible atom, when the mind is engaged in contemplating the myriads of worlds in whose bosom we seem lost like a grain of dust amidst a heap of stones. But because this imperceptible atom is under our feet, and the sun a distance of ninety-five millions of miles from our earth, whilst the stars are too far removed for me to assign them a place, all these attracting forces lose so much of their power in travelling from the depths of the sky, that by the time they reach us, the superior, because nearer, attraction of the earth renders the more distant inappreciable. The roar of a cannon is louder than my

voice, yet if one were fired off at a great distance from us whilst we are talking together, you would not hear it, and my voice would easily drown its thunder, weakened by the distance it would have to travel.

With regard to us, the earth's attraction possesses no rival. We are incontestably subject to its power, and were there not another force within us capable of struggling against the former, we should remain fixed to the ground like all inanimate objects, which, containing no opposing force within themselves, remain immovable, so long as no foreign power interferes to withdraw them from that influence which is ever attracting them toward the earth.

This is what constitutes the weight of bodies. We measure it by the amount of effort necessary to raise a body from off the ground; in other words, the effort required by us to overcome the attraction the ground exercises over it, for it is unconscious of the resistance which it offers us; a resistance which frequently calls forth our indignation. When you stiffen your muscles in order to take a jump, or, if you prefer it, to enable you to lift up the seventy or eighty lbs. weight, which you can easily do, the difficulty you experience you must attribute to the earth and not to your body, which has nothing to do with it. In itself it possesses no more real resisting force than a stick placed before me would have if I wished to draw it toward me; all its strength is in whatever pulls it. Supposing you held the stick the resistance would be very trifling, I should soon succeed in gaining possession of it; if your brother held it, the struggle would be greater, still I should conquer in the end, whilst if a horse pulled it, I should be obliged to yield, the stick would then be stronger than I am. The same law applies to the weight of bodies. Just

imagine your slight, little frame transported to the surface of the sun, where, for reasons which it would take me too long to explain, the force of attraction is twenty-eight times greater than on the surface of the earth, and, light as you really are, when there you would weigh from 1,680 to 1,940 lbs. You would have no power to jump. Nay, what am I saying? you would be unable to take a single step, or even to stand erect. Again, imagine yourself on one of those little planets which astronomers now discover by the dozen, and where the force of attraction is about twenty times less than on the earth; in this instance we should find a little girl weighing less than a four-pound loaf, and able to take a jump of forty feet without exerting more strength than she now requires to enable her to step across a ditch two feet in width.

As you see, all this is merely a question of opposing forces, and I was quite correct, when I spoke to you of weight, in stating that one must be strong to be light. Let us thoroughly understand one another; the lightness that consists in occupying ourselves with trifles has nothing wonderful in it; it is like the lightness of the little girl in the tiny planet, though even amidst this lightness there are people silly enough to put on a serious air. But he who faces the world's difficulties and tramples the greatest of them under foot, treading his onward course alert and joyful, lightly bearing the tenfold weight accumulated on his head, is he not stronger and more praiseworthy than, let me ask you, he would be if he allowed himself to be crushed by his burden, and reduced to a level from which he would be unable to rise?

But apropos of gravitation, you will fancy, perhaps, that we are losing sight of this famous centre of gra-

vity, in speaking of which I became entangled in this long explanation. Keep your mind at ease, we are coming to it.

Balance the two sides of a pair of scales equally, the beam which supports them being unable to depress the one side without elevating the other, and the earth attracting its two extremities toward it with equal force, it follows that, because the two suspended weights are equal, the beam remains undecided between the two attractions, which, though equal in energy, proceed from different attractions, and by its immovability keeps the bowls of the scales in a state called equilibrium.

This point settled, do you recollect the median line I spoke to you about some time ago, which, beginning at the top of the head and continuing in the direction of the nose, divides the body into two exact halves, equal in weight, one being a repetition of the other? If these two halves were left to themselves each would speedily fall to its own side, one to the right the other to the left, by the attraction of the earth, which disapproves of bodies remaining at a distance from it. But these halves being firmly united by the median line, mutually uphold each other, the right half being unable to respond to the call from the earth without dragging its companion, which, on its side, is drawn to the left, and *vice versa*. They thus form an equilibrium, and, provided the uniting line remains intact, nothing will fall.

Now, imagine a second line separating the body, front and back, into two other parts of equal weight, so long as the median line maintains its place it will suffice, will it not, to prevent the body from falling either backward or forward? Again, if you imagine a third line equally dividing the body between the head and feet, by placing

a point of support under that line, you will be able to retain the body crosswise, and prevent one-half carrying away the other. The principle is always the same, so we shall not have to go over the ground again. At the point where the three lines meet in the interior of the body there will be a central point common to all the three, the rallying point, so to speak, and around which, consequently, the earth's attraction, which exerts its power over each part of the body at the same time, will counterbalance itself in every direction. If you have carefully followed all that has gone before, it must be quite clear to you that so long as this point is upheld by a proper support, a fall must be impossible. Well, then, this point is the centre of gravity.

You have perhaps found this long explanation a little wearisome, but what can I do? It is the office of this naughty centre of gravity to fatigue people. From it proceeds all the discomfort we experience when we remain standing too long, and our loins ache so. They complain of having been obliged to watch over the centre of gravity in order to keep it in its place, from which it is always endeavoring to swerve, just like a turbulent child pulling at its nurse's hand in order to hurry forward at the risk of sprawling on the ground. Now that you have made the acquaintance of this servant, I propose telling you how he transacts his business in the various positions of the body.

CHAPTER XVIII.

ATTITUDES—(*Continued*).

If the vertebral column ran exactly through the centre of the body as the wick does through that of a candle; if the hole in the skull where the vertebral column joins it were immediately in the centre of the head; if the femur and tibia fitted firmly and exactly into their sockets; then standing would cease to be a fatigue. The centre of gravity would be directly upon the line of the principal beam of the edifice, the summit of which would be perfectly poised, and the supports of the body being deprived of motion, it being once placed erect would remain so, supported by bones no longer susceptible of experiencing fatigue, without the least intervention of the muscles to establish an equilibrium which nothing would derange.

Unhappily, such is not the case. What am I saying? It is, indeed, a happy arrangement. We have been formed to move forward, and not to remain stationary; if the measures taken to facilitate our walking had to succumb to the advantages of immobility, we should lose too much by the exchange.

First of all, the vertebral column is found toward the back part of the body, and the weight of the organs contained in the chest and stomach tend to drag it forward throughout its whole length. Again, the head if left to itself, would fall upon the chest, and still further increase the preponderance of weight on the front of

the column. Lastly, there are only rounded surfaces to the joints of the femur and tibia, which are always ready to glide one upon the other, and the bend of the two bones which meet obliquely at the knee continually causes them to swerve at the point of contact.

The muscles must then be constantly in play to resist these impulses, and bear up against these sources of weakness. Those of the neck pull upon the head so as to hold it back. Those which fill the empty spaces between the vertebræ all along the column, draw the whole body to it. The extensors of the femur and of the tibia stiffen to keep these bones in position, and from head to foot there is a perpetual struggle between the external force, proceeding from the earth, which strives to accomplish the fall of our movable framework, and the force that is within us which enables us to preserve our upright posture.

Now our muscles—the agents of this interior power, a necessary one, because its antagonist is always present, our muscles—as I have already informed you, are short-winded wrestlers, and require to rest at every moment. This is the reason why absolute immobility is so fatiguing, or, to say better, impossible to preserve. Just take notice what occurs when you are obliged to stand without movement; from time to time, the knees yield and then return to their position, the body stoops forward and draws itself up again, an imperceptible oscillation of the head occurs without your being conscious of it. These are the extensor muscles, which relax at intervals only to brace themselves up afresh. As the moments of repose are necessarily very limited, the merciless weight never giving any truce, the poor extensors, upon whom all the work devolves, soon ask to be released, far sooner than if you were walking, for then the extensors and

flexors must each take its own turn, and they have longer time allowed them for repose.

Have you ever remarked that when you are standing you involuntarily keep your feet at a little distance from one another, placing one rather in advance in order to make your balance more sure? You have very often done this, and yet I feel pretty sure you never thought that, in acting thus, you were enlarging your base of support. Here is another term of which I must teach you the meaning.

Our centre of gravity is placed at the top of the sacrum, to the front in the interior of the body. In order to secure a body from falling, the perpendicular of its centre of gravity, that is to say, the line of direction passing from it to the ground, must fall within its base, or on the space comprised between several points of support. This is what is called its basis of support, and you can readily understand that the more extended it is, the more margin is allowed to the centre of gravity above it, within which to balance itself.

This is why quadrupeds are so well balanced upon their legs; their centre of gravity has the whole space between their four feet for a supporting basis, and so they are superabundantly guaranteed against all chance of falling.

We, on the other hand, have no basis except our two feet, and well it is for us that we can enlarge it by placing our feet apart, when, owing to the relaxing of our extensors, our centre of gravity oscillates. As this tendency is to fall forward, it is also in the same direction that we naturally increase our basis by advancing one foot. Besides, the very conformation of our feet is in accordance with this tendency of the centre of gravity to fall forward. They lengthen in a vertical sense, and when we are standing it is not upon the heel, but on the

middle, more frequently at the extremity of the foot, that the weight of the body falls. Try to stand steadily upon your heels, and see how very difficult it is to preserve the centre of gravity perpendicular to this base. If you make the same experiment on your toes, you will find it easier, unless your calves, by the fatigue you experience, do not soon warn you that the extensors of the foot, which are lodged there, cannot endure the necessary effort required to sustain the body for any length of time, and so cry out to be relieved.

We are also able to displace this valuable centre of gravity on which the common safety depends, whenever it threatens harm, and we can transport it to a place of safety, like a nation which changes its capital to preserve its independence. Do you see this tight-rope dancer, who has only for his basis of support an inch of hemp, upon which the famous perpendicular must fall to a nicety, under pain of carrying all along with it, if by any mischance it swerves to one side. Here it is not a question of enlarging the basis, which is invariable, and the centre of gravity no longer needs oscillate. He must change his position each moment, so as to preserve the centre of gravity immediately above the cord. For this purpose rope-dancers make use of a long pole, which the dancer holds in his two hands, passing it from right to left, according as the movement of the body causes an excess of weight to fall to the one side or the other. Skillful dancers dispense with the pole, and shift the centre of gravity from one point to another, simply by balancing themselves so as to maintain an equal weight on either side. When not quite sure of our footing, or when afraid of our centre of gravity misleading us, we instinctively adopt these measures, and throw out our arms so as to recover our balance. A person who

is not master of his basis must yield to it, and follow where it leads him, if he wishes to avoid falling ; this is a maxim you should never forget.

There are certain cases in which the centre of gravity is, in spite of ourselves, thrown beyond its usual limits, and we are then compelled to vary our position, according to the new conditions presented to us.

Suppose now that I place a heavily laden basket upon my back, my centre of gravity immediately passes to the opposite side of the column ; its perpendicular falls behind my heels and changes the duty of the muscles. In this instance the flexors are the ones to contract, that they may bend the body with its burden forward ; we are then in no danger of falling backward, and the extensors take a holiday.

On the other hand, what happens to the women who go about selling apples, and carry their merchandise in front of them, on flat baskets strapped to their waists by a belt? If they were not to throw their body well backward their centre of gravity would be put in peril, from the weight of the basket. You may easily see how they throw themselves backward upon their loins, and waddle as they walk, fearing to bring their feet too close together, lest their balance should be disturbed.

This is exactly the position a very stout person naturally assumes. If he stood quite straight, his unfortunate perpendicular would fall beyond his toes, so he is compelled to tighten the rein lest it should carry him too far.

Lastly, endeavor to lift with one hand a pail filled with water. Your whole body will lean to the opposite side in a moment, and you will plant one foot as near to the pail as possible, and always for the same reason, that the combined weight of your body and the pail may

find their point of equilibrium above the space comprehended between your feet.

Thus it is, that amidst the continued struggle carried on by our muscles against the power of the earth's attraction, instinct comes to the rescue, and enables them to triumph over it. So long as you unconsciously resisted in the way an animal does, I say it was by instinct; let us understand each other. Now that you know why you do so, it will be the result of reason if you give yourself time to think about it; not that you are likely to carry out the rule any better than hitherto, but what a difference!

To any one seated, the struggle soon becomes a less severe one, because the very position obliges us partly to yield to the wishes of our imperious mother, the earth, who unhesitatingly attracts toward her whatever has emanated from her bosom, and she has no longer to reclaim what has been given to her. The legs, those thin vacillating props which we have always to keep an eye upon, are no longer taken into account, and the centre of gravity is perfectly poised, situated as it is only a few inches distant from a base sufficiently large to guarrantee its perfect security. Nevertheless, a great deal remains to be said. The struggle still continues in the upper part of the body, which, unless held in check by the muscles of the vertebral column, would incline forward. Those of the neck are also obliged to work continually, so as to prevent the head from falling. Let but sleep intervene to benumb the muscular action for a moment, and the chin soon drops on the chest, and continues its downward tendency, until this inexplicable instinct within us, which watches over our entire economy, rouses it from its torpor by one of those sudden starts so familiar to all of us in such cases.

There are two ways, then, in which assistance may be rendered to the muscles, the first of which is to seek a support behind that shall receive the weight of the upper part of the body. For this express purpose backs to our chairs have been invented. The second is by leaning forward upon the elbows, just as a house that leans to one side must be propped up by beams ; and indolent people, who prefer yielding to carry on a struggle, are in the habit of adopting this plan at table. I mention this casually, because I know you to be a well-brought-up little child, and that your mother never suffers you to lay an elbow on the table. Besides, there is really no necessity for it. The muscles are like ourselves ; when once they are accustomed to working they think nothing of it.

The moment when the supplementary point of support is especially useful is when we are kneeling ; the extremity of the tibia upon which the weight of the body falls does not stretch forward as the foot does, and the centre of gravity has no other balancing margin at this side. Thus the body instinctively throws itself backward, the femur begins to revolve in its socket, which gives way, and as the fatigue of resisting this bending for any length of time would be too much for the extensors, and especially in children, whose bones in this region are still rather soft, unless a great effort is made, the femur gradually falls, until at last the poor children are found seated upon their heels, which is neither a pretty nor a comfortable position. Between ourselves, it is very cruel to keep these little creatures too long upon their knees, whether it is done by way of punishment or to teach them to pray to the good God, who, I am sure, never requires that the body shall be suffering whilst the heart is ascending to Him. The Prie-Dieu has been invented

for the relief of the extensors of the femur during the time devoted to prayer ; they permit the body, by leaning with the arms upon the back of the chair, to advance its base of support in front. The centre of gravity is thus enabled to fall beyond the knee without any risk, and the toes no longer need to be doubled up under part of the weight of the body.

Lastly comes the attitude of complete rest. The earth can ask nothing more from a man who is lying down ; he has fully yielded to its attraction. God forbid that I should say a word against the horizontal line so dear to lazy persons, and so welcome to diligent ones when their strength is exhausted. Ungrateful, indeed, would the individual be who could attempt to speak slightingly of it, though we must agree that it is the least glorious of all positions. There is, after all, some glory in small creatures like ourselves being able to resist this large mass of earth, and excusable as we may be when we finish by succumbing to its power, it is not after all less a defeat.

I have nothing to say to you about this horizontal position. Those who do nothing can have nothing to relate. Our muscles have no more to do after they cease to dispute with the earth the weight which we have handed over to it. There is no longer any necessity for maintaining the centre of gravity above its base. The base is everywhere, and the innumerable perpendiculars emanating from all points of the body, abandoned to themselves by the universal fall, are always sure to meet again. By our abdication we avoid all fatigue as well as all danger. It is more certain and more convenient, but, I repeat it again, it is less glorious ; the superabundance of points of support deprives us of all movement. The Hindoos, who neither pride themselves upon their energy

nor their self-love, have a proverb to express this cowardly state of blessedness arising from the absence of struggle and movement: "It is better to sit than to stand, to lie down than to sit," and they add, "to die than to lie down." They should begin with the latter. Those who prefer life to death would do well to reverse the proverb.

Now, do not let this prevent your going to bed willingly the instant your mother tells you, my dear child. Human weakness has rights which it would be imprudent not to recognize, and it would never do for you to feel it a humiliation to be obliged to rest yourself. Even nations must rest sometimes.

CHAPTER XIX.

MOVEMENTS OF THE HUMAN BODY.

Before I speak to you of our different movements, I must say a word or two upon movement in general, and the laws by which it is governed, otherwise you would be unable to understand the subject properly.

As far as we know, we occupy the highest place in the scale of animal existence, and it is with some degree of pride that we call ourselves kings of the creation, of course of the terrestrial creation. We must not, however, think too highly of our royalty, inasmuch as those among us who are really kings are subject like the rest of us to the ordinary conditions of human life, suffering in their turn just like simple mortals, so the kings of creation are subjected to the same laws which act on everything below them. The matter of which our body is composed obeys these governing laws with the same exactitude that everything else does, and the laws of its movements are the very same as those which regulate the movement of stones. You need not feel offended at this, for they are the same laws also which govern the motions of the stars. Nothing is insignificant in their sight, nothing too important. They are divine, and it can be no disgrace to any one to obey them.

All bodies therefore, our own included, are of themselves incapable of movement; they are alike unable to impart or remove their motive power. It is in some sort

a guest lodging within them who goes out and comes in at will, without the host being able to interfere.

Motion is change, the result of the action which different forces exercise over bodies. I am almost afraid of explaining to you what a force is, lest I should in any way puzzle you regarding a term the sense of which ought to be so very clear to your mind. Besides, we have already made use of the word several times without any explanation. The power by which the earth draws toward it whatever would fly from it is a force. The energetic contraction of the muscles, bending or straightening our limbs in obedience to the will is a force. The spring that relaxes in order to repel whatever it encounters in its progress, is a force, and certainly a very important force, since it is the one that propels our balls and our bullets, and causes our steam-engines to work. All these forces determine the movements required for the bodies on which they act. Try to find me a body capable of movement, without a power to set it in motion. You will never succeed in doing so.

I am going to tell you something that will appear very strange to you at first, but which you will soon understand ; it is this, that when once a force has set a body in motion, though the force should suddenly be withdrawn, as is the case with a contracted muscle when it becomes relaxed, the body would always continue in motion, if the effect produced upon it were not destroyed by other forces acting in a contrary direction. Thus when you jump in order to cross a ditch, if some magic power were to transport you suddenly far from the earth into the void of space, this little insignificant bound would impel you onward indefinitely, and you would become a little star carried away, like your fellow stars, in an endless course.

This makes you smile, but just reflect for a moment. What makes you alight upon the ground after being lifted from off it? It is the ever-jealous earth recalling you to it: you understand it all now. If the earth were not there to recall you, what would there be to stop your course? One would be rich all one's life with a halfpenny in one's pocket, provided there were never any occasion to spend it; with a jump such as yours you would continue moving forever, if nothing came in the way to neutralise it.

You will perhaps not have noticed a remark I recently made, "Far from the earth in the void of space." I had my reasons for employing the word void in my supposition. No charity can equal that possessed by bodies when in motion. They cannot meet with other bodies and not share equally whatever movement they have derived from their motive power. It seems as if they always carry their provisions with them, and distribute them as they journey along.

Only this charity is not capricious and arbitrary, like ours. Bodies have not the same freedom that souls have; everything connected with them is regulated by fixed, inexorable laws. These are called mathematical laws, and we must have recourse to our arithmetic to enable me to explain in what manner this compulsory division of movement is accomplished.

A boy with twenty pennies in his pocket meets a party of nineteen poor fellows whose purses are all empty, he gives a penny to each, and at once all are equal. You can fancy how such a game would soon ruin the richest man in the world. Well, this is the game that bodies play; when a boy, who has received his New Year's gifts, meets a group of poor children who have had no presents, that is to say, when a small body set in motion

by a force meets with a large immovable body, it scatters its abundance through the whole mass. When a party of wealthy people meets with a poor boy, that is to say, when a large body set in motion encounters a small one at rest, they subscribe among themselves, and give to the new comer a share equal to each of theirs, and if many new comers fall in their way, the whole band will eventually be ruined.

Now the atoms of air in the midst of which we exist are as many minute bodies, and your little person, unimposing as it may appear in the eyes of the world, is a very formidable colossus when compared to them. But as, in your transit through the air, you would be continually called upon to distribute some of the provision you had received, however minute the part bestowed on each of these atoms might be, so little would at last be left to yourself that it would not be worth speaking about. You see my supposing you placed in the void in order to insure the perpetuity of your celestial course was not amiss, and in fact the heavenly bodies do assuredly traverse space ; nothing is more certain.

But all this is merely a supposition ; a chimera impossible to be realized. Nothing can rescue terrestrial bodies from the action of the immense globe on which they rest. Let me tell you what happens when any power robs them of its attraction for one single moment.

It is a long time ago, and yet I recollect it as vividly as if it had happened only yesterday. I was at school, and was very fond of amusement, and a great player at ball ; a most wholesome recreation for boys, and one I would gladly recommend to you, were it not that you are unfitted for this game owing to certain peculiarities connected with your clavicle, which I have already explained to you. It was a great delight to me to throw

my ball with all my might high into the air, so that I might catch it in my hand as it fell, without changing place. It was always a fresh cause of wonder to me to see it go up with such rapidity at first, then gradually slacken its speed, then stop and remain immovable for an instant, just as if held in the air by some invisible hand, and afterward begin to come down slowly, as if with regret, accelerating its speed little by little, and at last falling into my hand with a rapidity which at that time appeared perfectly startling. A big boy, a philosopher, as those youths were termed who were admitted to the dignified lectures on physics, one day told me that the ball, on reaching my hand, had precisely the same rapidity as it had on leaving it, and sorely did I rack my brain in the hope of discovering a satisfactory reason for so strange a problem. It is very simple.

You know the story of the Wandering Jew and his five halfpence, the most substantially rich man on record, because no matter how frequently he distributed his halfpence, the full sum was always to be found in his purse. Now instead of this Jew's inexhaustible store, let your imagination suppose a large bag swelled out by five thousand halfpence, but devoid of all magic charm, and the possessor obliged to give away five of the halfpence at each step he takes ; if he takes a thousand steps, it is quite clear that when he reaches the thousandth he will have nothing left. The bag will not be worth as much as the unpretending yet never-empty purse of Ahasuerus. But supposing the owner of the bag, on retracing his steps received five halfpence at each step he takes, he will, on arriving at the thousandth, naturally have precisely the same amount as at the commencement of his journey ; viz., five thousand pence. This is too clear to require any explanation.

It is the history of the ball thrown straight up into the air. The impetus given it on leaving the school-boy's hands was given once for all ; no matter what is expended, nothing will be renewed, any more than a young man who has extravagantly run through his patrimony can at the same time spend his money and keep it. It proceeds from one of those forces called spontaneous, because their action is only felt during a very brief moment.* The attraction exercised over the ball by the earth in an opposite direction is, on the contrary, a continued force. This is the term employed. Its power is as constantly expended and restored as the halfpence of the Wandering Jew. You are aware that when two opposing bodies meet, the stronger can only gain the victory by leaving a portion of itself equal to its rival upon the field of contest. A word, however, may be said in favor of these combats. They are in accordance with justice, and the majority would reverence the minority a little more than they do, if the latter could only be suppressed upon these conditions. But what am I talking of, my dear child ? Majority and minority are alike matters of indifference to you ; why is not this the case with the whole world ?

To return to our ball, however, it can only ascend by paying a ransom to the earth, that is to say, by sacrificing a portion of its motive power equal to the force of attraction it has to overcome ; so, as this is a continuous power, no sooner overthrown than it is again to be found at its post, ever ready for combat, the ransom becomes an incessant one, and the impetus given to it gradually

* In this instance, the spontaneous power is the sudden contraction of the muscles directing the arm upward, which, from being kept in check by its numerous guardians, conveys its impetus to the ball, so that it voluntarily leaves the hand at the moment the latter re-opens, to allow it to escape.

diminishing, the ball consequently slackens its speed in proportion, until the period arrives for the last payment to be made. Then comes a time of rest, a brief moment during which the little remaining power makes a last effort, in order once more to overthrow the obstinate force of attraction; finally, this power of attraction, henceforth without a rival, seizes the fugitive, leads it back triumphantly, though slowly at first, for it is modest on setting out. But as the impetus of the ball was always on the decrease during the ascent, it will continue to increase with the descent; the cause of the increase in the latter instance will be precisely the same as that of the decrease in the former. The increase and decrease of the rapidity are alike measured by this continuous force, which is ever being renewed, and which at length attains to a point where there is no longer any antagonist to neutralise it as fast as it is produced. The money-bag on its return home becomes replenished with exactly the same amount it possessed at the commencement of its journey, and the ball returns to its starting-point with precisely the same motive power with which it was charged at the onset.

I hope you begin to feel a little at home with these laws of motion, which perhaps seemed somewhat alarming at first. They are not more formidable than any other study, especially when not pursued too far, and when we are satisfied, as at present, to understand all thoroughly as we go along. I will only ask your attention for another moment, and then pass to something else.

I spoke to you a short time ago of the ball quitting the hand involuntarily, being projected into the air by muscles which, most happily for us, retain the arm in its proper place. In a similar manner I was once involuntarily pitched out of a carriage, the horse of which taking

fright, galloped off as if it were mad, and then suddenly came to a stand-still ; and I can assure you, from personal experience, that the law of motion that caused the ball to ascend so quickly treated my royal person in the most unceremonious manner. I found myself seated upon the ground, having gone over the horse's head, before I had time to think what had occurred.

This cavalier law is the selfsame as that which throws you violently to the ground, when you attempt to alight from a carriage moving rapidly. Your parents must remember a fatal accident that took place in Paris above twenty years ago. I refer to the death of a prince called the Duke of Orleans, who, had he not fallen a sacrifice to an accident of this kind, would probably now have been on the French throne.

When you are in a railway carriage, you experience no particular sensation ; nevertheless, you have within you a force capable of killing you if you gave it an opportunity of revealing its presence. Everything in that train is carried along by one and the same movement ; if it travel at the rate of thirty miles an hour, you may consider yourself a projectile impelled at this speed. As all that surounds you is travelling with you at the same time and at the same speed, there is nothing to make you sensible of the enormous amount of motive force you possess, and thus you travel up and down the line, devoid of apprehension.

If two trains were running along side by side at an equal speed, you would be able to jump fearlessly from one to the other, the speed of the carriage you jumped into being precisely the same as the speed of the one you quitted. Your own speed would consequently undergo no change, it would be exactly as if you jumped from one end to the other of the same carriage.

But you must never think of jumping out of a car in motion. The terrible thirty-miles-an-hour movement that is carrying you along, having no cause for relaxing, will continue to impel you forward, so that, when your feet touch the ground, which is immovable, your body will be hurled forward with a violence sufficient to break your bones.

If the train were to be suddenly stopped by any insuperable obstacle, this merciless motion would show you no favor. Your body would continue moving, at the risk of being dashed against the sides of the car. The same law would also hold good with the cars themselves under similar circumstances. When the engine meets with an impediment, the cars at the end of the train continue their course, regardless of the obstruction; thus they may be seen mounted one upon another, mutually spreading destruction amongst themselves and the poor passengers inside.

When I spoke of the earth as immovable, bear in mind that I only made use of the term in comparing it with the movement of the train. Whilst you are seated in your chair by your mother's side, you are as safe as any little girl can possibly be, utterly unconscious of all chance of harm. Yet there is within you at this present moment what would kill you at least a thousand times over, could the supposition I am about to make be realised. This earth, which you would say is so immovable, is carried along in its course around the sun at a speed of about twenty miles a second, if we are quite accurate, and take in the fractions, which would make a great addition to the speed at which our trains run. Now you naturally share in this frightful impetus, just as much as if it were a carriage, and what is more, every single thing on the earth also shares it with you. What

a catastrophe, then, its cessation for one single instant would involve! Can you in any degree conceive the result? Why, you, the house, this city even, would disappear, like so much chaff before the wind. Your plight would be far worse than mine when I was hurled out of the carriage.

I leave you with this idea, which is calculated to inspire you with respect for the laws by which the world is governed, and I pass on to our insignificant movements. You are now sufficiently acquainted with the subject to admit of my giving you their history.

CHAPTER XX.

THE MOVEMENTS—(*Continued.*)

When a drill-sergeant teaches his recruits to march, and gives the word of command, "Forward, march," etc., at the word "Forward," he makes them stand with the left foot carried well to the front, raised from the ground. This is called dividing the step. We are also going to do the same.

Stand perfectly upright, your two feet drawn together in line, as the unarmed soldier does, and remember you have to advance your left foot first. Your body imperceptibly balances itself, and your centre of gravity is immediately transported to the line of your right leg, which has, for the moment, to support your whole weight. The left leg, relieved from duty, bends at first, thanks to the action of the flexors, which raise it from the ground by contracting it; then the extensors straighten it and carry it forward. This is the first half of the movement.

At the word of command, "March," the centre of gravity at once passes to the right leg, the body bends toward the extended foot, which falls to the ground, and you have made a step. You see it is a very simple affair.

The body, now balancing on the left foot, lifts up the heel of the right one, which, touching the ground only by the toes, is quite ready to move. The flexors raise it, the extensors throw it forward. The centre of gra-

vity returns to it: it falls, and the whole process recommences. You can walk thirty miles in this way, provided your legs are sufficiently strong.

Thus you see, as I have already told you, that the flexors and extensors kindly divide the work, and you understand, do you not? how it is less fatiguing to walk than to stand still, a simple fact, which many people will hardly be convinced of. It is not, however, the less true, that every step we take is a fall, and that it is only by a succession of falls that we are able to advance. This is by no means flattering to our vanity, but what does that signify if we really make progress?

This continual oscillation of the centre of gravity, which perpetually changes from one leg to the other, gives a regular motion to the body while walking, especially observable in sailors, who, accustomed to walk upon movable floors, instinctively walk with their legs considerably apart, so as to enlarge their basis of support. Consequently, on shore, they have a rolling walk, which is far from being graceful, and as by separating their legs their steps are shorter, the result naturally is, that sailors are in general bad walkers. But they resume their superiority at sea, and those who walk well on shore would be only too happy when on the deep, and in a ship which rolls with the waves, to possess the sailor's free step.

Another consequence of this oscillating movement is, that the right side of the body, being habitually stronger than the left, and thus at every step gaining an additional impulse in advance of the other side, we should, without knowing it, if the eye did not guide us, walk obliquely toward the left, to continue the language of the drill-sergeant, language which does not require explanation. For this reason, nicely would he be taken in, who, walk-

ing in the dark, fancied he was keeping in a straight line.

This brings to my mind a souvenir of my youth—a long grass-plat in the Park at Versailles, called the "tapis vert" (green carpet), and which is in front of the lake known as "La pièce d'eau des Suisses:"—all who frequent the gardens at Versailles must be well acquainted with it. I do not know if the Parisians of the present day keep up this game of the golden age, but formerly it was not uncommon on fête days to see the good folks set off, with their eyes bandaged, from one end of the tapis vert, with the intention of walking to the other end. And it was seldom, indeed, that any one succeeded. The ignorant, going where the right side shoots out, found themselves all at once on the sidewalk to the left; the knowing ones, who had heard that the danger lay in going to the left, forcibly turned from that side, and arrived victoriously at the sidewalk to the right! So true it is that there is nothing like seeing clearly for keeping you on the straight path, and that a blind guide is always a bad one.

What I lately told you about the kindly division of labor between the flexors and extensors only holds good whilst walking upon level ground: the moment you begin to climb, this equality disappears; then it was only necessary for the body to proceed from one fall to another, now it has to be lifted up at every step, and of this the poor extensors have the whole burden.

Observe as you go up stairs:—

As soon as you have placed one foot on the first step, the foot left behind, below its companion, does as you do when measuring your height with a friend who is taller than you are, it rises on the point, elevating its own side as well as it can, to put itself on a level with

the other. This work is performed by the extensors of the foot. They are in the calf of the leg, as you know, and their contraction draws up our old friend the calcaneum, or heel-bone, which in rising pushes the tibia before it, with all which it supports. At this moment the body is carried forward on the more advanced leg, which, by stiffening, thanks to the extensors, completely raises it up. On this occasion it is above the knee where the work is done, and if you place your hand there at this moment, you will feel how rigid the muscles of the fibres become, in order to replace the tibia and the femur on the same level.

What renders the effort more necessary is, that the centre of gravity must be drawn, cost what it may, on to this line, for it is the moment when the foot lowest down the stair is about to be raised from the ground to join its companion; and the same thing takes place whether you ascend by single steps, or, as some big girls do, by two at a time. The same series of efforts recommences at every step; and if your room happens to be on the sixth story, you will probably feel rather tired on arriving there. Now, where do you feel this fatigue, if you please? Even if you did not know by experience, you could guess it from what we have just told you. It is in the calf, and the knee, but more especially in the latter, since here the greatest strain is made on the centre of gravity. Moreover, the upper part of the body requires to bend well forward, to render the operation easier, and in ascending a mountain a person naturally assumes this position, without it being necessary to tell him to do so; in fact, if the ascent is very long, he will at last almost bend himself double. Try to go up stairs whilst holding yourself very upright; your knee will bitterly complain before you have reached the first story;

or, rather, be prudent—take my word for it—and do not try. The least accident which would retard the centre of gravity, after losing its support below, would make you fall backward, and your mother would never forgive me.

Well! you are up stairs at last; now you have to go down again. Here the extensors of the calf and knee have only playwork to do—it is a mere nothing that is required of them. It is gravitation that manages the whole, and, if allowed, the work would progress only too rapidly. One may truly say of this movement, that one advances by a series of falls, and the only effort necessary is to see that the centre of gravity does not advance further forward than the feet. You may have seen coachmen, when driving down a steep hill, pulling back the reins to hold in the horses. The coachman in this instance is the bundle of strong muscles we have in our loins; they are placed just behind the steed, who would like nothing better than to break away; and they contract right over him, to bring him back to them. The upper part of the body, which a short time ago bent forward, in order to assist the loins, now bends back, to aid them in taking its weight upon themselves. And I would still less advise you to try putting your head forward while descending the stairs, than leaning it back while ascending. I really do not know why I have spoken to you about this, as I am very sure you never thought of doing such a thing.

You may, however, possibly have thought of running down stairs; if so, I beg of you never again to do it. Remember how very tyrannical are the laws of motion over bodies once on the move. Your own body, after it is set going, no longer belongs to you. You may have the misfortune to lose your equilibrium by a mere trifle,

and, instead of stopping to give you time to recover yourself, the motion within you, indifferent as to whether your arms or legs are broken, carries the little machine rolling down to the foot of the staircase, always accelerating its speed, like the ball falling to the ground; and if you are bruised on arriving at the bottom step, whose fault is it?

But we will not think of this any longer. A sensible girl, who knows the laws of motion and their pitiless rigour, will avoid trifling with them, or fail in paying the respect she owes to her centre of gravity, by making it gallop when it simply wishes to walk.

We say then that the work is performed by the loins when we descend. You cannot therefore wonder that the loins are tired when you have been walking downhill for a long time. The calves of the leg and knees, on the contrary, which have had nothing to do, are fresh and active, and a person who reaches the base of a mountain, worn out with fatigue, is quite surprised, if he does not know the reason, at finding himself rested as if by magic on the level road, although he is still walking. He has changed horses, like a post-chaise, and these are fresh steeds which carry him on.

One word more about the step. If your papa has sometimes let you ride upon his knee, you must be acquainted with the three different paces, trot, canter, gallop. It is about the last of these three that I am going to speak. The gallop is done by lengthening the step as much as possible. You will perhaps recollect that before long your knees and calves grew very tired, just as if you were climbing. Do you know why this was? It was simply because you were climbing the whole time.

Take your scissors, and make them go through the three steps, first the trot, opening the points a very little

way, then the canter, opening them a little wider, then the gallop, opening them as wide as you can. In proportion to the separation between the two points, you will notice that the scissors descend. This is precisely what you do when you stretch out your legs; your height is depressed, and as you take back your full stature each time the legs are brought to the same level, the muscles which have the care of raising the body have exactly the same duty to perform as when you walk up-stairs.

I have taken a long time to teach one, my dear little child, who can trot along so well as you can, how to walk. When you are older you will hear of a celebrated writer of comedies named Molière, who was also a great philosopher, although he used to philosophise in a jesting manner, which, after all, is not a bad way of doing. Whilst telling you all this, I am forcibly reminded of a character in one of Molière's plays, a Monsieur Jourdain, who is told how he pronounces *a* and *o* and *re* and *da* and *fa*, and he is delighted at the information, but, as his servant says, he speaks none the better for it, and I ask myself whether I have not been playing the part of this individual's master of philosophy toward you.

It is very certain that the first time you tumble, all the notions I have just given you about the centre of gravity, etc., will be of little use in helping you, but one would be very wrong if one only cared to see an immediate use for what we learn. Knowledge is not always available. We cannot eat it, it will not clothe us, we cannot put it in a shop for sale, nor can we shut it up in a box, or make a present of it; nevertheless, without it what would become of us? To accustom one's self to understand clearly what one does is one of the most useful things in the world. I have already said, that it is the true way to walk erect through life: you have not

yet attained to this point, but you will do so some day; and, setting aside all other considerations, you will not be sorry, when you have little children of your own to teach to walk, that you understand how they learn to take their first steps.

CHAPTER XXI.

THE MOVEMENTS—(*Continued.*)

If I had a scholar fifty years of age, I should scarcely require to proceed further with the history of the movements. The explanation of the step would no doubt be sufficient for his special use. But with a young lady, who is continually running and jumping, I can scarcely stop there. Running and jumping are both interesting subjects, of which it would be a pity not to speak.

Running is properly speaking, merely a series of successive leaps. I must therefore begin by speaking of leaping.

Would you like to see with your own eyes how a leap is made? It is very easy. I will teach you a game which amused me when I was—well, I will not say how old.

Take a strip of rather firm paper, and roll it between your fingers into the form of a tube. This tube will be composed of a series of spiral rings which you can tighten or loosen at will. Leave them sufficiently loose to slip one within another, press the tube on the table, holding it by the top, and when it has become quite short, like a shut-up telescope, open your fingers suddenly ; the tube will then jump into the air, and rise pretty high, provided you manage this cleverly.*

What renders it so active?

* By drying the tube thoroughly, either near the fire or in the sun, it can be made to jump to a far greater height.

It is the elasticity of the spiral rings, which are like so many compressed springs. They make an effort to return to their former position, and when you open your fingers, which hold the tube captive, taking the table, which repels them, as the basis of support, they dart forth, carrying the plaything into the air.

Recollect now what you do, when you wish to jump with both feet together. You begin by bending your loins and knees as much as you can. This is the work of the flexors, and you represent the little shut-up tube. Then all at once the extensors come into play, the body draws itself up quickly while pressing the ground, and the motion thus given launches you into the air, exactly as if you were a strip of paper.

Only, as comparisons can never be exact between things so very different as your body and our little paper toy, the spring which carried you forward is much more complicated.

Bend one of the bits of whalebone, always to be found in a lady's dress, by the two ends, in the form of a bow, and then suddenly let go—the bone will dart forward, dragged on by the two ends, which hasten to resume their natural position.

We have a bow in us which straightens itself when we leap. It is the vertebral column. Mark well what you do in this case. You not only bend your limbs, but also your body, and both straighten themselves at the same time, the moment you spring. The vertebral arch then makes a start, the rebound of which acts upon the loins, just behind the centre of gravity, which it propels forward.

But this is not all.

What do you do when you want to jump a little distance? You first balance your arms backward and for-

ward several times, and then throw them forward with all your strength, at the very moment you make your spring.

What have you now done?

You have called to your assistance that terrible law of motion which smashes a railway train if stopped suddenly; you have developed in the upper part of your body, by balancing your arms, the germ of movement, if I may thus express myself. It becomes serious when you throw your arms forward, and all the body works together from head to foot—to carry itself forward below, by the stiffening and straightening of the legs; in the middle, by the vertebral column; in the upper part by the jerk of the arms, which draw on the shoulders, as a pair of horses draw a carriage forward.

How many things are connected with a little leap of two or three feet! But, my dear child, this involves a fact of much more serious import than the act of walking. There you struggle, it is true, against that tyrannical love of the earth, which wishes to have you whether you will or no. But you struggle whilst making the earth your support, and the feet are responsible for the rest of the body, of which they bear all the weight. Here you perform an absolutely independent act; you abandon every basis of support in effecting the movement, and it requires the unanimous concurrence of every member of a body as heavy as yours is, if you wish to shake off the yoke entirely. Try to jump while throwing your arms back, and you will see whether the lower part of your body could go far without the assistance of the upper part. I do not propose that you should try to jump by throwing the upper part of your body forward without taking any trouble about the lower part. It is quite clear one might manage in this

way to break one's nose, and, in short, no one ever thought of trying it.

But we have not yet done with leaping.

Have you ever seen people dance on the tight-rope? I ask you this question, because it is an art which is gradually disappearing, notwithstanding the feats of its latest performers; nor is this, in my opinion, to be regretted. These artists at all times enjoy a singular privilege. They spring in the air much higher than other people, their bodies straight as an arrow, without apparently owing anything to the vertebral arch or to the extensors. Still, assuredly, they are not sorcerers; for these no longer exist.

Another agent is here at work, as well as the body. The rope on which the dancer falls gives way with his weight, and then it also rights itself in its turn. The shock which it gives to the feet resting on it, when it straightens again, sends the dancer back into the air, as it would throw back a beam that might fall upon it in place of him. Henceforth there is nothing more to do, and the springs succeed one another without further fatigue to the artist, except that of scrupulously maintaining the centre of gravity vertical with the cord. Besides, this is quite enough to attend to, when one considers the unpleasant prospect the poor man has before him, if he miss his mark. I do not sympathise with people who are pleased with this kind of amusement.

Whilst we are speaking of feats of strength, I must explain those wonderful springs to you that are made at the circus, to the great amazement of the simple, and by which a man can jump over a platoon of soldiers shouldering arms, with fixed bayonets. These are called the exercises of the spring-board—and what then is a spring-

board? It is a flexible plank, elevated at one end, upon which the jumper falls from above, when he wishes to astonish the spectators by making a marvellous leap. The plank acts like the dancer's tight rope, and all the honor of the feat would be due to it, if it were not also necessary that the human projectile should know how to make use of it. We must be just to every one.

You also, my little friend, without being one whit more knowing than the heroes of the circus, you make much less preparation for a jump, and you jump much further into the bargain, when you take a run before you spring, and the reason of this is quite simple. Gravitation and motion are, as I have often told you, two rival powers which dispute the body, and, whenever one establishes itself, the other disappears, or, to speak more correctly, is annulled; for it is a tenacious guest, and will not allow itself to be turned out of doors. In running, you put yourself in motion, and this motion would carry you on alone quite well if the feet stopped suddenly. You had some experience of this, when foolishly racing with your little friends through the beds of the kitchen garden; your feet became entangled in the gardener's measuring-line, and your head continuing its course, without asking your leave, popped into a bed of lettuce, which, happily for you, had been newly weeded. He, then, who springs while in the act of running, already possesses an acquired speed, as it is called, almost sufficient to effect the leap; he has, as it were, only to strike the earth with his foot to enable him to take flight. And now see what is to be gained by bestirring one's self. One gathers strength while journeying along.

After all, running is, as I have already told you, merely a succession of jumps. It essentially differs from

walking, since, in the running step, the foot left behind leaves the ground before the one in front has secured its basis of support; the body therefore finds itself, as in jumping, supported in the air by the power of motion alone. This rapid pace can naturally only be acquired by considerable effort. I have told you before, when speaking of the "work of the organs,"* how much the heart and lungs are engaged at such times, and how they will at last succumb to their task when the race becomes too prolonged. It is on this account that good runners, when they wish to accomplish a long distance, throw their shoulders well back, and straighten the upper part of the body, so as to enlarge the chest by widening the ribs, and thus securing the action of their muscles, by rendering the basis to which they look for support as firm as possible.

There is also another reason for drawing back the shoulders, a reason which is instinctively felt by the greatest novice in the art of running. We have seen in the chapter on "the Attitudes," the watchfulness which must be ever in exercise over the centre of gravity, always so imprudently inclined to cross the barrier beyond which lies a fall. This temptation is much stronger when the body, carried forward by its rapid career in the direction of danger, seems only, as one may say, to skim the ground with the ends of the toes. I beg you to notice, if you have not already done so, that we never place the foot flat upon the ground in running, as we do in walking; this would occupy too much time. It falls on the toes to rebound immediately. Those persons who in ordinary life feel that they are not well protected, redouble their precautions, and the body does the same in running. It throws itself backward, and while I call

* See "History of a Mouthful of Bread," p. 200.

your attention to these things, notice them yourself when you run. The faster you go, the more your head and shoulders bend backward, to counterpoise the lower part of your body, whose chance of losing its equilibrium increases with the rapidity of the race.

It is also to act as a counterpoise that our arms swing backward and forward with an inverse motion to our legs, the arm at one side going back at the same moment that the leg of the same side comes forward. An equilibrium is thus more easily maintained, and the centre point of gravity, which governs the whole, is brought back each time to the basis which it cannot abandon without ruin to the edifice.

You see that in order to run many precautions have to be adopted. Nature takes them for us when we are ignorant of them, and, quite unknown to us, our body arranges itself as the laws which rule it desire. But this does not dispense with our becoming acquainted with these laws. A mind that has any respect for itself would feel ashamed to know less than the mere instrument of its will.

There are many things I could still tell you, my dear child, about the working of this "walking machine," I cannot return to our old term without a feeling of pleasure, the study of which has already occupied so much time, and cost so much trouble, at least, to myself. I trust it has not been the same with you. All things considered, I think enough has been said. If I should try to make you too learned, I should only be laughed at for my pains. Not that this is anything very terrible, we must not always be afraid of being laughed at, but I might perhaps end by wearying you, and of that I am always afraid.

You now know from top to bottom the framework of the walls of the house you inhabit, to borrow the expression of an English author, a far more wonderful house than any king's palace, since it walks, and the walls are living. It remains for us to study the more curious part, but unfortunately also the most difficult for the mind to take in; the power which makes it walk, the invisible breath which causes its walls to palpitate. We approach the great mystery of life. Most certainly I cannot explain it to you, but you may at least learn in what it consists, and what more can one know of a mystery?

Before leaving this world of bones and muscles, whose difficulties appear to me like child's play compared with that on which we are about to enter, I wish you to carry away with you one useful reflection.

You have observed the solicitude with which your body constantly watches over its equilibrium, how, if I may so express myself, it exercises its wits, how it invents, how it endeavors, how it expends science and will to maintain itself erect upon its basis of support. Do not permit your soul to do less to preserve its uprightness. It is also called to rise toward heaven, and, like the body, it has its struggles to sustain, with the attractions of earth. Pride and earthly yearnings, the lusts and appetites of the flesh, constantly tempt it to stoop to things below; and it would soon lose sight of the higher regions of honor and devotion, which are its heaven, if it ceased to hold itself steadily on its basis of support. Now this basis allows no one to balance himself upon it. It is the conscience which we are forbidden to force, under penalty of rendering it useless. On this account you must pay great attention, and call to your assistance all the helps you possess, in the shape of

knowledge and will, to keep you straight on the inflexible line of conscience. On this account, be indulgent to the faults of others. When a poor man has fallen down on the pavement, every one tries to give him a hand, and if he has hurt himself, every one hastens to lift him up. Do not forget, my child, when you are grown up, that you must deal gently and helpfully with fallen souls, for there are none more deeply to be pitied, since the sorrow they work for themselves is the greatest that can be imagined.

And in the meantime, endeavor to fall down as seldom as possible, and if any one tumbles near you, whether brother, sister or companion, assist him or her to rise, like a good little girl, without giving yourself any airs; otherwise take care of yourself, for, however firm you may imagine your équilibrium to be, the centre of gravity is always exposed to mischances where the heart is not in the right place.

CHAPTER XXII.

ELECTRICITY.

Electricity! You will imagine, in reading this word, that we are losing sight of the subject which we ought next to study; viz., the nerves and brain. But I have not lost sight of it, I only wish to prepare your mind to comprehend as much as can be comprehended about them.

I recollect an idea which pleased me greatly, many years ago, when I undertook the duties of Professor of Natural Science to some young ladies. It occurred to me that man, being placed in the highest rank of creation, all its own known laws would naturally centre in him, and he being thus, as it were, an epitome of the whole, the explanation of these laws, as exhibited in him, would make their action elsewhere sufficiently plain. Setting out with this idea in mind, to which I have already alluded in the beginning of the history of the movements, I wished to limit my entire course of natural science to the explanation of the human body, reserving to myself the right of becoming discursive by the way, when it might become necessary to make you understand the phenomena we might meet with. I have been compelled to relinquish this plan, because, I acknowledge it without blushing, I have found the execution too difficult for myself, and, I may say, for my pupils also.

You must have already noticed since we began our conversation on the life of man, that I have often been

obliged to introduce other topics than the human body, in order not to leave the most interesting points in its history in obscurity.

Could you have understood anything of the mechanism of the lungs, if I had not informed you what was meant by atmospheric pressure?* or of the results of respiration, without my little lesson on oxygen, and its marriage with the body? Did not our study of the subject of animal heat oblige us to make acquaintance with hydrogen and carbon? and did not the composition of the blood require us to touch on chemistry? This subject we should have thoroughly explored, had we been capable of doing so. And again, not long ago, in speaking of the movements, we were obliged to branch off into dynamics,† a word that would have frightened your mother on your account if I had let it slip. When we come to describe the eye, we must, whether we like it or no, speak to you of light, and optics,‡ as natural philosophers term it. When we arrive at the ear, we shall then have to study the laws of sound, or acoustics,§ as they are called. We shall, however, only touch on these subjects, since that will be sufficient for you: we should go deeper into them if we intended to study them thoroughly.

You can now see that the study of the human body touches on everything, and that whoever completely masters it, knows all there is to know of physical laws. What I have just said may seem to you a little strong, but it is weak when compared with the expression

* See "Mouthful of Bread," p. 139.

† Dynamics in Greek means power. Dynamics is the study of force, or power with regard to motion effected by it.

‡ From the Greek word "opsis," signifying vision.

§ From the Greek word "acous," I hear.

of Pascal, where he says, "He who thoroughly understands a grain of sand understands the universe." And Pascal was right; whence I conclude that I need not feel alarmed at the boldness of my own expression.

But all this will not interest you. Let us now speak of electricity.

You know the yellow amber used by men as mouthpieces for their pipes, and by the women of the East for their necklaces, which I fancy would be much admired in our own country, if they were only more expensive. When next you see a piece of this substance, so soft to the eye and touch, I recommend it to your notice, for with it originated the idea of the electric telegraph. Moreover, its own merits sufficiently recommend it to the attention of inquiring minds, for it is one of the antiquities of the globe. It is derived from the resin of old pines, which grew long before the era of man, in the forests of the North of Europe, and from time immemorial it has been fished for—for it is really a fishery—along the shores of the Baltic, the waves of which tear it from its bed, by breaking up the sand beneath which it lies buried. The ancient Greeks, who were intrepid merchants, went to buy it from the savage tribes on the borders of the Vistula and Elbe, by sailing northward from the Euxine Sea,* by the great rivers of Scythia. It is a great pity, we may observe in passing, that not a single record of these expeditions has been preserved, for undoubtedly they must have possessed some. The Greeks were far too fond of narration to lose so good an opportunity. In short, they were well acquainted with amber, and gave it the name of electron.

* The Euxine Sea of the Greeks is now called the Black Sea, and their Scythia extended over all the steppes of the south of Russia of the present day.

Theophrastes, who lived three hundred years before the Christian era, tells us that in his time they had recognized a singular property in amber, that of attracting light bodies when it is rubbed. Rub a piece of amber, and then place it near a bit of thread or a fragment of straw, and it will at once fly toward it. This will give you an idea of the trifles which lead men to great discoveries, and how often the great laws of nature may, so to speak, lie within reach of man, without his thinking of extending his hand to seize them. He who had dared to announce to the worshippers of Jupiter Tonans* that the mystery of the thunderbolt lay hidden there, in this fragment of straw adhering to a morsel of amber, would most certainly have been taken for a madman in that age, and might perhaps have been invited to drink hemlock, in company with Socrates, the despiser of the gods. Unhappily, they did not think so much instruction could be concealed in a child's toy, and human science made no advance on this point for two thousand years.

At length, about the beginning of the seventeenth century, a man appeared who thought of examining this singular play of the amber and straw, so long considered as merely an insignificant caprice of nature, more accurately. It was an English physician, Dr. William Gilbert, respectfully termed by a learned man of the last century, whose book I have in my hand, the father of modern electricity, and whom we seem to lose sight of, now that his discovery is of world-wide renown. Such ingratitude is by no means uncommon. For my own part, I do not hesitate to rank the day on which the English physician rubbed his first bit of yellow amber, amongst the great days of the history of man, although people take no note of it. He ended by discovering that this prop-

* Jupiter the Thunderer.

erty belonged to other bodies besides the electron of the Greeks; and to him belongs the imperishable glory of giving the first hint. It was soon perceived that we were in presence of an element, up to that time unknown, which was to be found everywhere, and to it the name of electricity was given, in memory or remembrance of the body which had manifested it in the first instance. Less than a hundred years after Gilbert, a new science was established, of which I shall give you a brief account.

Suspend a piece of paper by a silk thread and then put near it a stick of sealing-wax which has been well rubbed. The paper will fly toward the sealing-wax, adhere to it for a moment, then will fly back, and if you pursue it with the sealing-wax, it will continue obstinately to recede, like two friends who beginning to embrace each other suddenly quarrel in the midst of the embrace. The experiment is easily made, and it will amuse you if you try it.

Next take a long and narrow vial or small glass bottle, so that you can rub it more easily. Recommence the play, and you will have the same results.

If afterward, taking the glass bottle in one hand and the sealing-wax in the other, you place one on each side of the bit of paper, you will produce another effect. The pendent paper will oscillate from one to the other, escaping from the wax after touching it, to run toward the bottle, rushing from the bottle to return to the wax, and each time adhering for a moment to the new friend it is immediately going to desert.

In all this you see nothing but a little amusement. The immediate successors of Gilbert might have thought like you. Let us do as they did, and go forward.

An explanation must be formed of these extraordinary movements. Here is what was first supposed.

Imagine two friends much accustomed to each other's society. They live peacefully side by side, happy to be together, but making no demonstration. Separate them, and they will only think of how they can meet again, and if they come in sight of one another they will throw themselves with transport into each other's arms. Well, in all bodies, there exists a double electricity, a couple of friends who say nothing when they are together, and whose presence we consequently forget.

When amber, sealing-wax, or any resinous substance is rubbed, one of these two electricities disappears, the other remains alone. The name of resinous electricity is given to the one that remains in the resin. When glass is rubbed, it is the resinous electricity which takes flight, and its companion remains faithful to the glass. This receives the name of vitreous electricity, and bodies are said to be electrified when one or other of these two electricities is isolated.

The friend left alone, whether in the glass or resin, ardently longs for its lost companion. Now this companion is everywhere present in conjunction with the other, but the bonds which retain it cannot be broken without great effort. When a body is not too heavy, and when it is near enough to the electrified glass or resin, it is carried by the force of attraction, which its disconsolate friend constantly exercises in its vicinity, to recall the companion to itself which it misses, and it flies forward and rejoins it.

This is what the Greeks witnessed, and you understand now why the bits of straw flew toward the amber, and also why the little paper alternately adhered to your bottle and the piece of sealing-wax.

But this is not all; once adhering to the sealing-wax, which possessed only resinous electricity, the paper gives

it all the vitreous electricity it contains, and, small as it was, it has not sufficient for its requirements; then what happens? It finds itself filled in its turn with resinous, having lost all its vitreous electricity.

Have you never met with people who cultivate your society while they can get anything out of you, but when that is ended, show you the door? This is what the sealing-wax does to its little benefactor, when it has extracted from it all its precious vitreous electricity, without much change in its own condition. It repels it, and this is the more easily effected since the paper no longer desires to remain in its company. All bodies electrified in the same manner repel each other mutually, and we resemble them somewhat; when two persons cannot mutually aid each other, they do not care to live together.

If the paper be placed between the wax and the glass, both being electrified, what will happen? Robbed by the wax of its vitreous electricity, it will go to refurnish itself on the glass which is fully provided. But in exchange for its present, the glass will remorselessly take possession of all the resinous electricity of the paper, and the poor little wretch will only have changed one state of misery for another; it will now find itself vitreously electrified. A fresh departure ensues, a fresh refurnishing from the wax, followed by a similar result, and thus ever backward and forward, until the paper, having effected an exchange, by conveying vitreous electricity to the wax and resinous electricity to the glass, until a perfect equilibrium is established between the two, and the paper recovers its own equilibrium. Then all is right again, and things in their usual state. There is nothing more to see, the game is ended, unless we begin rubbing again, and so recommence the process.

You can imagine that the thing could be more quickly done by suppressing the intermediate agent; viz., the paper, and merely suspending the glass bottle and the sealing-wax side by side. They would then go to each other, and make the exchange themselves by reason of a second law, which is the fellow of the first. All bodies electrified in an opposite sense mutually attract each other. This law we also understand. How often do we see persons of different characters sympathize with each other, each friend delighting to find in the other what is not to be found in himself?

If it depended on myself, my dear child, I would give you no other theory of electricity. This is far the nicest, the easiest to understand, and the most pleasing to the imagination. But unfortunately there is another, and, what is still more unfortunate, it is to this other theory the names belong, which are in use at the present day, so I am obliged to explain it to you also.

Prepare, then, to take leave of our two friends, the resinous and the vitreous. They are now out of fashion, but, nevertheless, do not forget them. It was through them men first began to understand something of this great marvel, electricity, and through them also children are most easily taught what electricity really means.

CHAPTER XXIII

ELECTRICITY—(*Continued.*)

THE naughty man who put our resinous and vitreous friends out of fashion was an American, named Benjamin Franklin. The idea which he substituted is a very simple one, and as it does not make any material change in the manœuvres of our small bit of paper, a few words will suffice for me to explain it to you.

There are not two kinds of electricities in bodies; there is only one, but its quantity varies.

The stomach of the man who has had just the quantity of food he requires is contented and tranquil; but an empty stomach, or one that is over charged, not only suffers, but each gives indication of its painful sensations. In the same way bodies which have the necessary amount of electricity give no sign of life. Those which have too much, and those which are deficient, are both equally in distress, or, as it is termed, electrified; the first has too much, the second too little, and hence the two names, positive and negative, are given to one and the same electricity. These two words are easily understood. The one which is overcharged is positively out of order, because of what is there, the empty one is negatively so, on account of what is not there. It is simply the negative and affirmative you find in your grammar.

When glass is rubbed, the electricity in it increases, and thus it passes into the positive state; when the wax

is rubbed, the electricity it possesses disappears, and it passes into the negative state. The first, then, desires to throw off its surcharge, and the latter to make up its deficiency. If you bring them into contact, the mutual understanding is perfect; they run toward each other, this to receive, and that to give. If the piece of paper is brought into play, it will fly alternately toward the rich side to relieve it of its excess, toward the poor one to offer to it all it possesses, and, becoming rich or poor itself by turns, it will be repelled by the party it has relieved, as soon as it can no longer render any service. Thus, as you see, whether there are two kinds of electricity, or only one, whether it is called vitreous or positive, resinous or negative, the effect produced will always be the same; bodies electrified in an opposite manner will always be mutually repellent. This theory of repletion and emptiness is by no means poetic, but if poetry loses, science gains, and this is of far greater importance. At the present day the terms invented by the American are the only ones in use.

I just now called this Benjamin Franklin a naughty man; I was angry with him for having robbed us of the two little friends that would have suited us so well; were he still living, he would not be angry with us for this; he was much too sensible a man for that. But, between ourselves, we have not spoken of him in terms of sufficient respect, for he was a remarkable man, and I much regret my inability to give you a little sketch of his history before proceeding; but take my advice, and read it for yourself the first time an opportunity occurs. In the meantime, I must tell you that it is to him we are indebted for the discovery of the important part which electricity now plays in the world.

You would be unable to understand anything of this

discovery, if I did not carry you a little further forward in the study we have already commenced.

First, seeing that electricity exists in all bodies, how does it happen that glass, resin, and a few other bodies, are the only ones that can be electrified by friction, the effect of which should be the same everywhere? Did you ever ask yourself this question?

In the middle ages, communication between different countries was neither safe nor easy; what one country produced, wheat for instance, could only be consumed where it grew, and thus whole populations might be dying from hunger, while the granaries were overflowing with corn scarce three hundred miles off. Now-a-days, thanks to our railways, and the universal security which prevails, when the harvest fails in one place, corn immediately flows in from all the countries where it is abundant, and those deadily famines which used to carry off the poor by thousands have become literally impossible.

There are some bodies in the same condition that we were in during the middle ages, and on the surface of which electricity cannot circulate. If they have too much in one point, so much the worse for them; this superfluity remains where it is. And again, so much the worse for those parts which have not sufficient; none comes to them from other quarters. These bodies are called non-conductors, they do not understand export and import, and this is the case with glass and resin.

There are other substances, especially metals, in which the transmission of electricity is accomplished with astounding rapidity; it is said, at the rate of ninety or a hundred and twenty thousand miles in a second. These are the good conductors, and you may rub them as much as you like; for as fast as they become electrified on one point, whether positively or negatively, the equilibrium

is immediately re-established throughout the entire body. Thanks to this rapid transmission, in comparison of which that of a railway train is like nothing! Moreover, it is right you should know that your own body is a pretty good conductor, and by means of your hand, which holds a piece of metal, the communication being established between it and the ground, the great common reservoir of electricity, according to the authorised expression, it becomes as difficult to impoverish or to enrich it, as it would be difficult, by pumping, to empty a well that was in communication with the sea, or to cause the same well to overflow by pouring water into it.

If, however, either glass or resin were placed between the ground and the metal that has been rubbed, the case would be different. The metal would be insulated from the great common reservoir by these non-conductors, which do not allow electricity to circulate on their surface. This is termed their insulating power; and then the metal may be electrified. If you were to make the wheels of a train run upon glass rails somewhat raised from the ground, the wheels would be electrified by the friction, and by their means the train would, in its turn, become electrified with all it contained. Can you guess what must happen the moment communication with the earth is established, were it even by means of a passenger putting his foot to the ground while holding on to the carriage-door? The whole would explode, and I will prove upon what grounds.

When your bit of paper adhered to the sealing-wax or glass, it was only able, on account of its size, to take from the one or yield up to the other a very small portion of electricity. Had it been put in communication with the inexhaustible reservoir of the globe, by means of a metallic wire, it could not even then have given or

taken much more electricity than before; because, owing to want of circulation on the surface of these bodies, the equilibrium could only be established at the point touched by the paper. On this account you neither saw nor heard what passed, for the re-establishment of electrical equilibrium is always accompanied by sparks and a crackling noise, proportioned, it is true, to the quantity of electricity set in motion, but this most certainly took place. Perhaps some microscopic animal lost in the minute recesses of the paper, as we should be in a mountain gorge, was struck down by the effect produced, but it was too weak to be perceived by you.

Suppose a large metallic surface insulated from the ground, strongly electrified,—this is done by means of an electric machine, which I have not time just now to stop and explain to you,—and then to have some body, which is a good conductor brought into contact with it; the equilibrium would instantaneously re-establish itself over the whole surface, by means of its prodigious facility of transmission. A torrent of electricity—if I may be allowed the expression—would rush from one body to the other, and its passage would be revealed by a bright spark, and a sharp noise like the crackling of wood. If the body which was the good conductor happened to be your own, you would experience a shock by no means the most agreeable, I can assure you; a sensation in all respects so peculiar that you must feel it yourself in order to realise it.

Enlarge the surface, the spark, the noise, and the shock increase with it, and if it attains certain proportions it becomes a flash of lightning, a peal of thunder, instant death for whoever may be bold enough to try the experiment. An electric machine the size of a railway train would kill a man as instantaneously as the lightning it-

self, and it would kill as many hundreds as happened to be in it at the moment of the discharge, which is the name given to the sudden re-establishment of equilibrium between two electrified bodies.

We now come to the discovery made by the great American; but before entering upon it, one detail more requires to be noticed.

I resume my supposition of a train electrifying itself on glass rails, with the prospect of certain death to the passengers at the first moment of contact with the ground. This will never happen, but there is no harm in imagining it. It is thus that fairy tales were invented, which grave men will do away with when there shall no longer be any children.

What is to be done to save these unfortunate travellers? If we touch them they are lost.

There is no difficulty in the matter. The train stopping of its own accord, I should cause it to be surrounded by a battalion of soldiers, with orders to cross bayonets at a foot from the carriages, and after five minutes pause the soldiers may with confidence give a hand to the travellers, and help them to alight; the danger is over.

You do not understand how this can be! and it is in fact as marvellous as any fairy tale. This wonder arises from a singular law of electricity, the explanation of which would take up too much time, but I can give you an idea of it in a few words.

Electricity is in a manner chained to the surface of bodies, when they are flat or round. It can escape far more readily when they terminate in a point; this is what is called the power of points.

My imaginary train, having rubbed on the glass, which becomes positively electrified, would itself become nega-

tively so; for you must recollect, that two bodies rubbed together electrify each other always in an inverse sense, one giving, the other receiving; from whence it results, we may remark in passing, that the same body is capable of taking indifferently either of these two states of electricity, according to the nature of the companion against which it is rubbed. The train would then most certainly have lost its electricity, and the danger to be feared from contact with an exterior body would arise from the immense torrent of electricity suddenly precipitating itself over so vast a surface to establish the equilibrium. Each bayonet directed toward it would have exactly the effect of so many tubes pouring streams of water with an incalculable rapidity into an empty basin; the basin would soon be filled. The same with the train; and the travellers, restored with it to their usual condition, could resume communication with the great common reservoir, the earth, without any danger.

Now I shall give a little account of Benjamin Franklin.

He was not exactly a learned man, for he was originally a printer, working for his daily bread, but liking study very much, and he wrote certain books for the improvement of his contemporaries, which will never go out of date, because they include the secret of all true manliness. From a book that happened to be sent from England, Franklin learned what I have just been endeavoring to teach you;* and the idea occurred to him, that since the discharge of an electric machine resembled, as it were, terrestrial electricity of a certain force, celestial electricity or the lightning of heaven, with its noise and its brilliancy, might after all be nothing more nor less than an immense electric discharge.

* We must except the power of points discovered by himself.

And he found that he was right.

Franklin had announced, three years previously, that by placing metallic wires on end, at a sufficient height insulated from the ground, and terminating each in a point, one could see them electrified on the approach of a thunder cloud, and he was waiting until a steeple, then in course of erection in Philadelphia, should be completed, that he might make the experiment. Tired of waiting, however, he at last constructed a kite with two sticks and a handkerchief, arming it with a metallic point, and one stormy day he went into the fields to fly it. A large black cloud passed over the kite, and Franklin received electric sparks by touching a key with his finger, having first fastened the key to the end of the kite string;* this was indubitable proof of the presence of electricity in the cloud.

This took place in June 1752; and now mark well the danger of delay. By waiting so long for the steeple, the illustrious American was not the first to realise the idea which he was the first to conceive. A month previous, on May 10th, at half-past two o'clock in the afternoon, the first electric spark drawn from the clouds, as one may say, was seen by a carpenter at Marly—the Marly of Louis XIV.—which will one day be talked of for this, let me tell you, much more than for its having been the occasional abode of the great king, for whom the world at large will care but little. Marly-le-Roi is near St. Germain, and belonged to Madame de Maintenon, for whom it was built by Louis XIV.

I must give you the history of this spark, which is more worthy of record than many a battle.

* The key was retained by a silken cord which intercepted the communication with the ground. Silk, as you perhaps know, is one of those bad conductors called insulators, or non-conductors.

Buffon, the celebrated naturalist, had undertaken to introduce the ideas of the Philadelphia printer into France, as he already begun to astonish the scientific men of Europe, who were somewhat mortified to see themselves left in the background, by one who had hitherto held no rank among philosophers. "As Buffon was occupied with more important affairs," says one of his contemporaries,* "he abandoned this duty to one of his friends named Dalibard." This Dalibard was an intelligent man, and had so strong a liking for the new doctrine that, impatient to know whether the inventor was right in his surmises, he could not wait till Franklin had tried his experiment. "It never thunders in Philadelphia," was already the byword in Paris, amongst those who were teased with Franklin's delays. I quote the expression to show you how little was known of America at that period.

Dalibard caused a pointed iron rod one hundred feet high to be placed on end, well insulated from the ground, on a property he possessed at Marly. As no storm occurred he returned to Paris, leaving the iron rod in charge of a carpenter, who had orders not to lose sight of it, in case the weather changed. The storm came at last, the iron rod emitted sparks, and thus it happened that, owing to the fortuitous arrangement of Franklin, Buffon, and Dalibard, this carpenter was the first man to see, with his own eyes, the fire of heaven coming down by command and exposing itself for the gratification of human curiosity.

These long-pointed iron rods that are seen rising from

* This phrase is taken from the first of the letters on electricity, (1752,) by the Abbé Nollet, one of the famous natural philosophers of the last century, who amusingly jokes the new comer as to his pretension of being able to invoke electricity by sticking up metallic points on the highest parts of buildings.

the roofs of large buildings, are the invention of Benjamin Franklin. They act the very part that our bayonets did a little while ago, and silently discharge from the clouds the electricity, which might destroy the edifice should they pass too near it. It is the iron rod erected at Marly, but with a most important alteration. Instead of being carefully insluated from the soil, the lower extremities of lightning-conductors are put in communication with it, and a thousand methods are invented to render this communication as complete as possible, otherwise, so far from being any protection, the lightning-conductor would become very dangerous, for the electricity of the clouds accumulating there, and finding no issue, would immediately discharge itself on the building, and thus we might bring down upon us a dangerous visitor, which, but for the conductor, might have kept at a distance.

Now when you see metallic cords reaching from the rods to the ground along buildings which are surmounted with lightning conductors, you will know what is their use, and remember you must never go near them during a thunder storm. The electric fluid, silent and invisible, is very probably there, and as the proverb says, "Let sleeping dogs lie."

Now, what do you say? Have we not made some progress from Gilbert's yellow amber, and the piece of straw adhering to it? and have we not attained to something more serious? Well! you have still more wonderful things to hear about. We shall by means of a frog's leg, arrive at a series of revelations which will even surpass all we have yet seen.

CHAPTER XXIV.

ELECTRICITY—(*Continued*).

It was in 1786, thirty-four years after the spark had been observed by the Marly carpenter, as has been described, that a physician of Bologna, Professor of Anatomy, set about preparing frogs, as they say in that country, with a view to scientific research; after having killed them he flayed them, in order to study their organization more carefully. As he prepared them, he hung them one by one upon his balcony, by means of small copper hooks passed through their loins at the very spot whence the large nerve, known by the name of the lumbar nerve, issues, and which is situated in the same locality in man also, for in the general plan of the nervous system we are not differently constructed from the frog. A breeze arising, caused a movement among the frogs, and each time that one of them touched the iron bars of the balcony with its pendent feet, it suddenly doubled up with a convulsive movement, as if the poor little dead body had begun to jump.

How frequently is human glory the simple result of chance! If this Professor of Anatomy had been standing at this moment with his back turned to the balcony, he would assuredly long ago have sunk into the same oblivion into which so many other professors of his day have fallen, who doubtless were as worthy of remembrance. But happily he saw the frogs jump, wished to know the cause of the phenomenon, and became immor-

tal! This man was called Galvani. When you hear the words galvanoplastic, galvanized iron, galvanic brushes, etc., etc., you will at once know them to be derived from the name of the experimenter on frogs.

Galvani at once understood the nature of the convulsion which appeared to resuscitate the little dead feet. He said to himself that the shock could only be the effect of an electric discharge.

But whence proceeded the electricity thus discharged?

Galvani being a physician, at once attributed it to the nerve and muscles which had been put in communication by means of a metallic circle. He declared that an animal electricity existed, of which the nerves were the conductors, self-producing in living bodies, and existing in them for some time after death.* He was right, but his discovery was only partial.

This opportune gust of wind sufficed to render two men immortal. Volta, Professor of Physics at Pavia, had the intelligence requisite to work out the remaining part, and so to complete Galvani's discovery. Being a natural philosopher, he laid aside the idea of nerves and muscles, and turned his attention to metals, declaring in his turn, that the cause of the discharge resulted from the contact of the two metals, namely, the copper hooks and the iron balcony, the one of which having attracted all the electricity from the other, had become positively electrified, the other, negatively. A celebrated controversy arose between the two professors, who both came off triumphant, a solitary instance, I believe, in the annals of science, and whilst Galvani successfully established his share of the discovery in obtaining shocks by

* After a certain lapse of time, a dead frog becomes insensible to the double contact of iron and copper.

placing the nerves and the muscles of the frogs in direct contact without the intervention of any metal, Volta established his theory, no less successfully, in the invention of the famous Voltaic or electrical pile that still bears his name.

Making his experiment the reverse of that of Galvani, Volta replaced the half-dead frog's legs with something inanimate, such as a piece of wet cloth, and from one experiment to another, he, at last, arrived at the conclusion, that the two metals most suitable to electrify one another in an inverse manner, by contact, were copper and zinc. He also found that the effect produced became more considerable, if a series of pieces of metal, copper and zinc, were always coupled two by two in the same order. This was the origin of his pile, formed with a certain number of couples, copper and zinc, piled one upon another, making a kind of column terminating above in a piece of copper, and below in a piece of zinc. No animal electricity could by any possibility be formed here, nevertheless the two pieces of metal placed at the extremities of the pile were electrified ; that of the copper negatively, that of the zinc positively. If two metallic wires were attached, one to each end of the pile, and the other extremities of the wires brought into contact with each other, an electrical discharge was produced, or rather, I should say, a continuous succession of discharges. The equilibrium constantly destroying itself as fast as it was established, scarcely had the electricity reached the negative extremity, ere it returned to the end positively electrified, from which the surplus always renewing itself was as constantly thrown off! Imagine a fountain which discharges itself into a cask without any bottom and through which the water returns again into the reservoir. It is quite clear that the cask

would never become full, nor the reservoir empty. And this is the case with the two pieces of copper and zinc placed at the extremities of the pile. If ever there was a scientific name happily chosen, it is this of electric current, given by Volta to this inexhaustible stream of electricity, which flows from the one piece of metal to the other.

This is a very different thing from the spark of the electric machine, even when that is magnified to the proportions of the thunderbolt.

I remember a game we used to play at school, called "The Stag." It began with a large herd of stags, pursued by one dog. If I recollect right I was delighted to be this dog. At the onset all chance seemed against him, but as soon as he caught a stag, it immediately became a dog, and had to assist in capturing another stag, which, in its turn, joined the pursuit, and thus by degrees, the pack gradually increasing in number, succeeded in capturing the last stag. This, in some measure, resembles the war commenced by man at his creation against Nature. Alone at the beginning, and as if lost among a thousand inimical powers, the combat seemed a very unequal one, but the first that he overcame immediately became his auxiliary, and it is by, in a manner, forcing each new captive to fight by his side, that he has at last succeeded in plucking so many feathers from the wing of nature, if I may be allowed thus to express myself.

Now, in a warfare of this nature, the importance of the capture ought to be calculated in proportion to the amount of service the captive can render, and the new form under which electricity revealed itself this time was a great boon to man. It is no easy matter to make the electric spark do our bidding, but an electric cur-

rent! can we control it? Think what we can make a stream of water do!

Scarcely was the pile discovered when it showed us what use it might be turned to. I have already told you that, in nine pounds of water, one pound of hydrogen and eight of oxygen are found. The very first experiment of the pile taught us this. Until that moment, no one had ever thought of seeking for anything but water in water. Water was, as you are well aware, one of the four elements* recognized by the ancients as earth, air, fire and water, and these four were considered as the universal basis of all bodies. An Englishman who, for the first time, was studying the effects of the new apparatus designed by Volta, was struck by a smell of hydrogen which could not be accounted for,† and by dint of observation, he at last convinced himself, that the water contained in the wet layers was decomposed by the passage of the electric current into two gases, of which the one, oxygen, went to the positive extremity of the pile, and the other, hydrogen, was disengaged at the negative extremity. It was an easy matter for philosophers to collect with exactitude, to measure, and to weigh the two gases thus produced, and they had soon a clear proof of the fact they maintained. By directing an electric spark through the two gases enclosed in the same vase, they effected an explosion accompanied by sparks. This was the reunion of the two disunited

* Element is synonymous with simple body, a word now used to express a body which as yet has not been decomposed into several others. At present we can number sixty simple bodies, but it is a list that is exposed to constant change from the discovery of new indecomposible bodies, or from the decomposition of old ones. Some persons are of opinion that there ought only to be two simple bodies. Perhaps there may after all be only one.

† Hydrogen has a peculiar odor, sufficiently distinct not to deceive a chemist's sense of smell.

gases, and only some tiny drops of water were found in their place; what the electric current had divided, the electric spark re-united.

The discovery of the true nature of water was made in the year 1800, and the discoverer's name was Nicholson. I wish you would accustom yourself to remember the names of these conquerors and the dates of their conquests. What are those odious little battles between men compared with the great and fruitful battles of man against Nature? And tell me, if you please, which deserves the place of honor in the memory of little girls?

These were sad times for the famous quatuor of elements, so long the undisputed fathers of all bodies. Only a few years before, the illustrious Frenchman, Lavoisier had at one blow divided the air into two gases, oxygen and azote, and scored out fire from the list of simple bodies by proving, scales in hand, that it was only an illumination produced by the union of gases.* Then here comes an Englishman to deprive water of its rank as an element; and seven years later another Englishman named Davy, another name I wish you to remember, gave the last blow to the sole survivor of the four, already in a very sickly condition, by discovering, thanks to the pile, metals in the earth.

At that time the name earths, in the plural, was given to potassa, soda, alumina, silica, magnesia; in short, to all those substances which, mixed together, form almost the entire composition of stones; and consequently the soil of our fields, which, though you may not be aware of it, is nothing else than pulverised stone. Nicholson's discovery concerning water led the way to similar dis-

* Lavoisier's theory, as it is generally understood, is, that combustion consists in or results from a combination of bodies, with the oxygen floating in the surrounding air.—Translator's Note.

coveries with regard to many other bodies, which all permitted of their bonds of affinity being broken up by the electric current; and what is singular, it was always the oxygen, or the portion in which this gas was most abundant, which appeared at the positive extremity; the other part invariably passed to the negative. In the year 1807, Davy, who had arranged a very strong pile, submitted potassa, soda, and their companions to the action of a very powerful current, and produced the result anticipated. The earths were destroyed, the oxygen appeared at its post, and potassium, sodium, magnesium, aluminium, etc., were successively discernible at the opposite end, and were henceforth classed in the order of the old metals—iron, copper, gold, silver, etc.,—under the name of earthy metals.

All these metals terminating in *um* sound very scientific to our ears. There is one of them, however, aluminium, that you must be acquainted with; for it has had the good taste to place itself at the service of young ladies in the form of trinkets, since a noted French chemist, Henri Sainte-Claire Deville, has found out how to obtain in ingots what the pile only produced in particles far too small for use. There is another which also appears destined to enjoy a brilliant future; this is magnesium, which is beginning to be used on special occasions for lighting, and a single wire of which, when burning, gives forth a light surpassing that of any lamp. If potassium were cheaper, its wonderful power of spinning round upon water, and darting forth actual fireworks, would long since have brought it into notice as an object of curiosity. I grant there is nothing very important in all this, but it is only the beginning, and the Davy's metals have not yet fulfilled their destiny. Aluminium is already making a very respectable apprenticeship as

an available metal in the industrial world; and if this were the only one, it would be sufficient to place the English philosopher in the rank of those who have extended the field of human knowledge. The French philosopher also deserves his share of praise; and we must not forget the great Italian who invented the pile. There is this advantage in opening up a new furrow in science, that all who have contributed to its development are entitled to our gratitude.

Unfortunately, we have not sufficient time to pass in review all the conquests due to the pile. Still I cannot bid adieu to Davy without speaking to you of the electric light which this sun kindles at our bidding, whenever we require it, by means of the pile.

It was Davy who produced the apparatus used at the present day to obtain those prodigious effects of light which enable workmen to labor in the dock-yards by night as easily as they can in broad daylight. The electric current produces these effects, by traversing small pieces of charcoal placed one after the other at the extremity of the two wires of a strong pile. If Gilbert, whilst rubbing his bits of amber, had been told that, by means of this simple art, one of his countrymen would, two centuries later, have invented a new light for the use of mankind, fancy how great his astonishment would have been! Nor would it have been less cause for wonder had he been told that, thanks to him, a day would come when silver spoons would be more common than pewter ones were in his day. You must understand that I am here alluding to galvanoplastics, of which I wish to speak to you more at length, inasmuch as it is far more nearly connected with the subject now occupying our attention than you can possibly guess.

In that celebrated garden of Greek roots, of which we

spoke in the chapter on Ruminants, (a ruminator is a man who muses,) we read this line which, had he seen it, would have extracted a grimace from Boileau,

"Plassô, forme, enduit, fait semblant."

Such as it is, it suits us, for it teaches you that galvanoplastic means coated by Galvani. It ought to have been voltaplastic to be accurate, but that is of no consequence.

You have just now seen that where the demolition of a body is effected by the current of the pile, the oxygen retreats to the side that is positively electrified, or carries off to that point its intimate friends, who remain hooked on to it in the struggle. The remainder runs to the negative side.

This being settled, recall to your mind those beautiful blue crystal pyramids which you must more than once have admired while passing the druggists' shops. The masses who have remained faithful to the name employed in the middle ages, call this blue vitriol; the scientific name is sulphate of copper. These blue crystals are full of copper; but try if you can extract it with your fingers! it is held there in bonds of affinity infinitely more complicated than those by which hydrogen and oxygen become water, and perhaps you will not be sorry, to speak in lawyer-like style, to know the condition of the contracting parties.

From the first union of copper with oxygen, a new body is formed, known as oxide of copper, which alone appears like a black powder. This oxide in its turn unites with sulphuric acid, which again is only a composition of sulphur and a large proportion of oxygen, and all these unions combined produce the blue crystal. There are a great many unions in this affair, are there not? but I am persuaded that you will be able to recognise them all.

You disentangled more intricate family webs than this the other day when you accomplished the numbering of the relationship to your cousin.

The current of the pile will soon unravel them, and what is more, partly untie them, if you will make it traverse a basin of water in which you shall have melted one of these blue crystals full of copper. It is a voyage which you can compel it to take by putting one part of the basin in communication with the positive and the other with the negative wire; it immediately rushes from one wire to the other across the bluish water, which is a good conductor, and sows discord among the component parts all along its passage. The oxygen which was united to the copper abandons it all on a sudden, and runs to the positive wire in concert with the sulphuric acid, upon which the copper, deprived of its oxygen, produces the same effect which a girl without a dowry, does upon a miser. The copper thus forsaken, liberated, as chemists say, makes for the negative wire, and on arriving there, behaves as amiably as we could desire now that we know how to make it subservient to our use.

If it encounters a metallic object there, or one simply washed over with a layer of metal, no matter how thin, it immediately makes friends with the comrade presented to it, and deposits itself all over the surface of the object in impalpable particles, penetrating the most remote corners, so that after a certain length of time all this surface is covered with a uniform layer of copper, a thousand times better applied than could have been done by the hammer of the best tinsmith of which the world can boast.

Bodies resulting from these double unions such as that of the blue vitriol, or sulphate of copper, are called salts.

If you dissolve salts of gold or of silver, or any other metal you wish, in a basin of water the operation will be exactly the same, but instead of a layer of copper, you will have a layer of gold or silver, as the case may be, which will adhere to the object attached to the negative wire. Hence all this new, cheap silver-plate, which rejoices the hearts of the humblest individuals.

When you eat your soup, if the useless luxury has been abolished in your house of using solid silver spoons and forks, you can say to yourself, that you are acquainted with the history of your spoon. It has passed through an electric bath of a salt of silver, out of which it has come plated. This coating, the coating of Galvani, is of incomparably purer silver than is that of royal spoons, when, indeed, kings condescend to make use of silver. Only I must warn you that it is exceedingly slight. Do not take it into your head to follow the example of a very zealous cook that I once knew, who scoured some electro-plated covers with ashes with all her might. What is noble on the surface only, is soon rendered ignoble by rough usage. On this account deal gently with your spoons; and that you may have nothing to fear from the rubs of the world, let your little heart be silver to the very core.

CHAPTER XXV.

ELECTRICITY—(*Continued.*)

The inconvenience, or if you prefer it, the advantage of study, my dear child, is this, that it always leads you farther than you thought of going. In order to prepare you to understand the action of the nerves, and the part they perform in your body, I have been obliged to speak to you upon a variety of subjects, each one more curious than the other ; and now, whether disposed or not, I am under the necessity of explaining the electric telegraph: an invention of the Almighty which dates from the first moment an animal began to move.

This electricity, which has for some time occupied our attention, is a very mysterious power. I do not know to what to compare it better than to an actor who by means of changing his dress, is enabled to represent all the different characters in a play. This power is to be met with everywhere, always the same in principle, but manifesting itself under different aspects, according to circumstances. We have seen it accumulating on the electrical machine, and instantly disappearing at the smallest contact. Again we see it carried away in the form of an endless current in the pile ; and I much regret that I had not time to enter into its whole history. You would have been amazed at the thousand forms under which it manifests itself.* Now we come to a new form

* The pile in use at the present time bears no resemblance to that of Volta, and in its construction and in the explanation of it, his first

of electricity, so different from the others, that, for a long time people were deceived about it, and believed themselves in the presence of a totally distinct power; but there is no longer any doubt on the subject; I refer to what is called magnetism.

Magnetism comes from the Greek word magnis, which signifies a magnet. You are aware that the magnet attracts steel. To be ignorant of a discovery made more than two thousand four hundred years ago would be a great disgrace. Thales, one of the fathers of Greek philosophy, taught us that the loadstone possesses a soul capable of attracting iron, and I should like his explanation well enough if we could agree about the meaning of the word soul. The natural loadstone such as was known to the Greeks, and the artificial magnets of the present day, attract iron, as a piece of amber that has been briskly rubbed attracts bits of straw. Here is the first resemblance between the power inherent in them, and that observed in the old Electron; but we are only at the beginning of our subject.

Ask your mother to lend you one of the needles she is in the habit of using. The probability is, it has become magnetised by the manipulation it has been subjected to by your mamma's fingers, while passing it rapidly and frequently through her work. You may also present one of the points of a pair of scissors in active use to the needle, and you need not be surprised

idea of the virtue of metals brought in contact with each other, has been completely abandoned. It has been recognized that all chemical actions, all changes in the conditions of bodies, and even a simple difference of temperature between one end of a metallic pile and the other, produce electric currents. The term pile has nevertheless been indistinctly applied to all the different apparatus invented since the time of Volta, for producing these currents, and with some justice, for from his pile originated all the more recent discoveries.

to see the needle adhere to the point. In this case, rub the needle freely against the two points of the half-opened scissors; magnetism being there, it will be communicated by the rubbing, from the needle to the scissors, just as good and bad habits are communicated from one to another by little girls who live together. But if this experiment do not succeed, for these little feminine implements are not without their caprices, and it is not every lady who is gifted with the power of magnetising with her fingers, you have still another left. Ask your papa to buy you a magnet; there are plenty to be had in every toy-shop at about a shilling or two each, and I can assure you it is as amusing a toy as any you can select. They are generally of the form of a horse-shoe elongated, the two extremities of which incline toward each other. Hold your needle by the middle, and rest the two ends upon the magnet, giving it a little see-saw movement; a moment will suffice to magnetise it.

In short, hold in your hand a magnetised needle any way you like. Before trying your experiment, satisfy yourself as to the direction in which the north lies from the point at which you take your stand. This is exceedingly simple. If you turn your face to the sun at mid-day, the south will be immediately in front of you, and the north consequently at your back.

This important point once settled, take a cork and cut a delicate round slice off it, and place it in the middle of a plate full of water. This will form a kind of little boat capable of carrying your needle; place the latter on the cork in any direction you choose, you may rely upon one end pointing toward the north, the other consequently toward the south; turn the cork and needles as you like, they will always by mutual consent re-

turn to their respective posts. The northern extremity turning from the south with horror, and that of the south fleeing from the north with all its might.

This, my dear child, is the compass; and I advise you to look with great respect upon this needle which turns about in the plate of water. Man is indebted to instruments of a similar kind to guide him on his way on the open sea, where he sees nothing around him but a boundless expanse of waves exactly resembling each other; and but for the unfailing instinct of these little needles, we should in all probability still be ignorant of the existence of the American continent. At any rate, our bravest mariner would tremble at the idea of venturing upon a voyage across the Atlantic, and so one half of our globe would be lost to us.

But this has nothing to do with our subject. Let us go back to our little magnet, for I conclude you possess one; it will best answer our present purpose.

Look at it well. You will observe the letter N marked on one of its extremities. This end will always turn to the north, if you hold the loadstone suspended by a string, and notice its movements. It is that end of the needle which rubs against it that you will notice points toward the south. Present it now to the other end of the needle, that which, like itself, is directed toward the north, and is called its north pole,* it will fly from it; reverse it, and present the south pole to the needle, it will rush toward it.

Do you not recognise in all this those fundamental laws of electricity to which I recently called your attention?

* These terms, north and south poles, have been given to the two extremities of the magnetic needle, to assimilate them with the two poles of the earth, which may be considered as a large magnet.

Two bodies rubbed against each other become electrified in a contrary sense.

Bodies similarly electrified repel each other.

Bodies differently electrified attract each other.

It is clear that we are dealing with facts of the same nature, and there is every reason to suppose the power producing them to be the same. But there is something beyond this.

Navigators for a long time observed, with despair, that in stormy weather, when the compass was most necessary to them, it sometimes indicated a route the reverse of that intended to be followed; turning at random, as if it had lost its head. Do not smile at my expression; it differs but slightly from that used by seamen, who in these cases speak of their valued compass as if it were a living creature, saying it is bewitched, or, in other words, gone mad.

Storms being ascertained by Benjamin Franklin to be nothing more than electrical phenomena, and this peculiarity in the movement of the needle having been so often observed, led to the belief that there was an evident connexion between magnetism and electricity. This supposition was corroborated toward the close of the last century by natural philosophers, who produced on the compass all the effects of a storm, nay more,* by means of the electric machine.

* Note for grown-up persons, taken from Cavallo's "Treatise on Electricity," 1785:—"A violent degree of electric power is not only capable of destroying the virtue of a magnetic needle or changing its poles, but can even communicate magnetic attraction to a body not possessed of it. If a fine sewing-needle be placed in the direction of the discharge from a glass tray of at least eight or ten feet square, the needle will in some instances become magnetised, and that while floating on water, and will turn toward the north. It must also be remarked that if, at the time of the discharge, the di-

Immediately upon the discovery of the pile, it seems to me that scientific men ought promptly to have tried the effect of its currents upon the compass; an effect much more easily ascertained, considering its constancy and regularity, than in the rapid and capricious discharge from the electrifying machine. It was not, however, until the year 1819 that a Danish professor called Œrsted felt himself in a position to announce to the world that the compass lost control over itself when in the vicinity of a wire crossed by the current from the pile. After the experiments described by Cavallo, if you have had courage to read the extract I made from them, the discovery, between ourselves, was not a very extraordinary one. This did not, however, prevent its making a great sensation; for Œrsted, a really scientific man, at the same time that he made the discovery found the means of utilising it. Thanks to him, the illustrious Arago was enabled, the following year, to establish the fact on which an entire telegraph system rests, namely, that a bit of soft iron* became instantaneously mag-

rection of the needle be east and west, the point that is struck will mark the north. If, on the contrary, the direction of the needle be north and south, the extremity looking north will continue to indicate it after the shock, no matter from which side it comes, and in this latter case the needle will be more powerfully magnetised than in the former. Lastly, should the needle be placed perpendicularly to the horizon, and the shock passed by one or other of its extremities, the lower one will always point to the north."

* In submitting iron to a certain process, it is rendered much harder and very brittle: it is then called steel, and ordinary iron takes the name of malleable iron, as opposed to steel. Iron wire, which is readily bent, is made of malleable iron. Needles, which pierce our work so easily, and snap asunder when we try to bend them, are made of steel. Steel and malleable iron have not the same magnetic properties; the former can only be slowly magnetised, taking certain precautions, and then it remains magnetised for ever; thus all loadstones are manufactured from steel. The

netised, so soon as the voltaic current, I do not stop to explain the word now, crossed a wire rolled round it, and that it ceased to be so, simultaneously with the cessation of the current across the wire.

This fact established, nothing was easier than to set up electric telegraphs. I have told you with what startling rapidity electricity rushes from one end to the other of bodies which are good conductors. Let a metallic wire be led out a hundred miles, a thousand if you like, and at the end of its journey let it be rolled round a bit of malleable iron. At the same moment if from the spot on which you are standing you send an electric current along your wire, putting it into communication with a pile of which you hold the one end in your hand, the bit of metallic iron at the remote extremity will suddenly become a magnet; this will be quite perceptible to any person wishing to see the experiment, as it will attract to it needles which may happen to be presented to it. At the very moment when by a slight blow of the hand you suppress the current by interrupting the communication between the wire and the pile, the artificial magnet will at once lose its borrowed virtue, and cease to possess any power of attraction. This is the principle of the electric telegraph; and as you see, it is very simple. The rest is only a mechanical affair, and I leave to some one else the task of explaining to you the various kinds which up to the present time have been invented.

Now, my dear child, we can pass on to the explanation of what is called the nervous system. I have made

second, namely, malleable iron, receives magnetic virtue immediately on its simply coming in contact with a magnet, and retains no trace of it after the contact is suppressed. It is just like children who learn their lessons very quickly and forget them as readily. There are also memories like steel, which require longer time to be acted upon, but in the end are none the worse for that.

you wait a long time, but it is because we shall find electricity connected with it. This universal power, which seems to preside everywhere, presides also, it is more than probable, over the mysterious acts of life in our bodies ; and it was requisite you should know something of it, before speaking of the nerves which may be considered as its agents. Only, it is neither the electricity of the electrifying machine, nor that of the pile, nor that of the loadstone either ; it is living electricity, if I may so speak, having no resemblance to any other kind in its manifestations, but which is not less the same power producing other results because exercised under different conditions.

The few remarks we have made to-day are quite sufficient to give you an idea of the possible transformations of one and the same power. You have, I presume, no longer any doubt regarding the intimate relationship existing between magnetism and electricity ; and yet I have not said all, for I might have shown you how electric currents may be produced by magnets, in the same way as we make magnets with electric currents. A magnet is therefore, in reality, a permanent battery ; and scientific men have so perfectly understood this, that they have given the name of poles to the two extremities of the pile ; the positive and the negative. But what a difference ! This battery is under your control. You can touch the two poles at the same moment, and put them in contact with a variety of bodies which would produce marvelous results if acted on by an ordinary pile. Nothing stirs, nothing reveals the presence of the marvelous virtue sleeping imprisoned within it. Iron alone has the privilege of awaking the beautiful sleeper ; it alone can set it working ; it alone can harbor it. What is the reason of all this? We know nothing about it.

What is the peculiar property of animal electricity, since I must give it its proper name? We know nothing of it either. I thought I would tell you this beforehand, lest you should come with exaggerated hopes to the study we are just entering on.

CHAPTER XXVI.

THE NERVES AND SPINAL MARROW.

I REMEMBER seeing, in the manager's office of one of the first-class hotels on the German border of the Rhine, a large frame, the interior of which was furnished with a variety of small labels, one or other of which, every now and then, sprung up with a sharp, quick sound; they were raised by an invisible wire, and exhibited a number; the number of some particular room, as you may suppose. The manager, thereupon, stretched his hand toward a row of numbered handles placed in a line in front of him, and pulled one of these, when a waiter immediately ran to attend the summons, no matter in what remote part of the house he was wanted.

In all this you have a representation—though but a rough one, it is true—of what goes on in your brain. From all parts of the body mysterious threads issue, for the purpose of carrying all their demands to it. The manager pulls the handle, and the waiters are at once on the move.

You must not, however, suppose that this is in all respects a parallel case. We are quite aware from what points these signal wires issue, but no person has as yet been able to discover their precise termination, nor can they determine accurately in what spot the handles used to transmit the orders are placed. In fact, the manager himself has never been visible, though assuredly he exists, inasmuch as there is something to be managed; but who

he is, and the manner in which his duties are performed in his office, are problems still to be solved.

The manager's office with its double play of wires, is, my dear child, to some extent, similar to our nervous system. We have now pretty well examined almost all our bodily machinery, and we cannot terminate our lesson better than by considering that portion which may be called its very soul. I speak now as an engineer would do, who sees a soul wherever there is a power, and means no harm in so speaking, though, it is true, he does not deal with intelligent powers; but we are not yet in a position to speak about intellect.

I do not recollect whether I ever told you what is meant by a system; at any rate the explanation will not be inappropriate here.

In philosophy, a system is an assemblage of ideas in harmony with each other, uniting in concert to establish a doctrine. In physiology it is a series of organs similar in structure, all accomplishing the same function, or, if you prefer the term, all occupied with the same work. Thus the assemblage of bones supporting the body constitutes the osseous system; the assemblage of muscles giving it motion is the muscular system, and so on.

Now a vast number of duties are required to be performed by this nervous system, of which I find myself forced to speak to you, much to my regret, I can tell you; for the more I reflect, the more I read and re-read my masters, the more I hesitate as to what I am to say to you about it.

First, then, as we shall presently see, it is an electrifying apparatus, and in this capacity it presides over the contractions of the muscles, which, to my idea, are nothing more than electric phenomena of a peculiar nature.

Next, it is an interpreter, informing us of what takes

place within and without us, telling us this in a very simple way, by the pleasure or the pain which attends each of its revelations.

Lastly, it is, what shall I call it? an indispensable condition without which we can neither think nor will; it is to us the organ of thought and will.

In all this we have just now only one thing to consider, undeniably the easiest, namely, the part which the nervous system plays in connection with our movements. This will complete our history of the walking machine, which has for so long a time occupied our attention. Another subject will immediately follow, which, if I were simply a naturalist, I would call "The history of the feeling and thinking machine;" but it is not a very attractive title, and would be as repugnant to you as to me; besides, it would not be correct, for concealed beneath the visible machine lies the invisible; so let us call it "The history of sensation and thought."

Let us now rapidly glance at the ensemble of this wonderful apparatus, which plays such an important part in our economy, and leave the details to follow in proportion as they become necessary.

Imagine a number of threads, the fibres of which being untwisted from below become entangled in all directions, and so entwine themselves as to form small strings at first, then small cords communicating from all sides with a kind of centre cord where they are bundled together. This is the simplest idea I can give you of the nerves and of the spinal marrow where they all meet.

These scattered nerve fibres, which when united form nervous cords, are extremely minute. The keenest eye is quite unable to discern them; however, thanks to the microscope, we know pretty well how they are formed.

Have you ever amused yourself by noticing to what an extent a string of treacle hanging from a piece of bread may be stretched? Just imagine one of these strings elongated until it becomes invisible to the naked eye, and encased in a fibrous transparent sheath. This will give you a very tolerable idea of the appearance of nerve fibre in an elementary state, as seen through the microscope. Gratiolet, in his beautiful book on the nervous system, compares the interior of the fibre to a glass thread, which bears some resemblance to our thread of treacle, as I presume he refers to melted glass.

It is this minute, imperceptible, transparent thread which is the important element of the nervous fibre; the agent of life, I should say; and each fibre is under the direction of that part of the body whence it proceeds, which it puts in communication with the centre; now to carry messages to it, now to bring back orders.

These fibres all run parallel to each other along the nervous cords, where they are enclosed in a common sheath, and there remain, each as direct and separate from its neighbor, as the different threads of a skein are from each other. They thus reach the spinal marrow, and continue their course to the base of the brain, at which point you can no longer follow them, and they become lost in the inextricable labyrinth of fibres intersecting one another in every direction in this mysterious region. Thirty-one pairs of nerves emerge right and left, from the spinal marrow through small holes or openings at either side, the whole length of the vertebral column, at the points where the vertebræ unite. They are like so many little doors, by which the agents of life scattered through the body, reach the universal meeting place in compact battalions; but at the moment of entry, those agents divide in each nerve into two bands, each

of which branches off into different directions. The one glides into the spinal marrow, at the edge adjoining the base of the vertebral column, the other by the edge in proximity to the dorsal apophyses, if you have not forgotten these old friends. I would call your attention, en passant, to this division made by the nerves as they approach the marrow. You will see by and by that something very curious is hidden beneath all this.

These two portions of the marrow—that in front and that behind, or the anterior and posterior portions—are separated from each other by a deep fissure which runs down the two sides. Another furrow, deeper still, divides it in the middle throughout its entire length into two equal parts; so that in reality we possess two marrows; one to the right and the other to the left. If you have been able to keep in your mind what I told you in my long explanations of the median line, this arrangement will not surprise you. You are aware that your body is composed of two halves exactly equal, at least in all that concerns the walking machine; it is therefore fair that each half should possess its particular marrow.

Each of these two marrows is, in its turn, composed of two substances. Everything, then, is in couples. The one is of a gray color, forming the nucleus; the other is white, serving as an envelope to the gray. Their consistency is about the same, resembling pulp. Just imagine two custards of different colors, the one enclosed within the other.

Probably all this affords you but little interest, my dear child; but have patience. You may consider this a kind of geographical lesson, the historical one will follow in due order, but it was necessary beforehand to introduce you to the theatre of action, so as to be able to make you understand what follows. Historians

adopt this plan when they come to great battles, and the nervous system is our great field of battle; it is there where the meeting takes place between mind and matter, to express to you, in familiar language, an idea that escapes when we wish to lay hold of it.

Now it seems that this meeting takes place in these two substances, the white and the gray, which we shall presently find spreading out at their ease in the brain. I may as well tell you beforehand, it will increase your interest in them.

Lastly, to end this description, which I am curtailing as much as possible, there is a triple membrane surrounding this precious and delicate assemblage upon which our life depends, and which were it less carefully packed up, would be injured by the smallest shock. The term packed up, seems rather trivial, but I cannot find one more fitting.

The membranes are somewhat oddly named; but never mind, I will give them as they are.

That forming the immediate investment of the spinal cord is called the pia mater; you need not appeal to me for an explanation of the expression, I have never yet met with one. This pia mater, to speak correctly, is only a prolongation of the fibrous sheath, which acts as a common envelope to the nervous fibres, which extends along the marrow, when they penetrate to it. It holds its contents very tightly together, so much so, that, in the event of the smallest rupture to the envelope, a protuberance is visible from the outside, and this support gives it a certain consistency, and in case of a shock, keeps all in its place.

The dura mater, a name of the same class as the preceding, forms, above the immediate envelope of the marrow, a second fibrous tube, much more voluminous than

the marrow, which would oscillate in it, in a most disagreeable manner for us, without an admirable arrangement of Nature, who has converted this dangerous void into an additional security.

For this purpose, the inner surface of the dura mater is lined by one of those serous* membranes, of which I have already had occasion to speak when treating of the synovia in the joints, which incessantly distil a fluid drawn from the serum of the blood. This liquid fills up the intervening space between the two envelopes ; and when you have to trust anything very fragile on a long journey, I think you can conceive no safer or more simple mode of packing it, especially if you adopt the precaution taken in this instance ; for on all sides, and all along the canal where the marrow swims, as it were, a resisting ligament stretches from one edge to the other, which controls the marrow, and retains it exactly in the centre of its liquid protector.

For greater security, the dura mater does not fit exactly to the sides of the osseous canal of the vertebral column ; if it did, the various shocks to which we are liable, would be too suddenly transmitted to the cord ; it is round, and the canal is triangular. The interval between them, caused by this difference in form, is filled up by a sort of stuffing, composed of the soft tissue, which adheres to the bone on one side, and to the membrane on the other ; and this, you will readily believe, goes far more toward breaking a shock, than any amount of hay can do in a hamper of goods.

Nothing short of all this it required, my little friend, to enable you to use your skipping rope as you do. The poor little pulp that you carry all along your back would

* This membrane, of an exceedingly fine texture, is called in Greek "arachnoid," meaning spider's web.

not make much resistance there had it been left at perfect liberty in the vertebral canal, like a chocolate cream in its crust.

One word more about the marrow, and we shall have done with it.

It does not descend to the lowest point of the vertebral canal, at least not in the same manner as I have described it. Reckoning from the second lumbar vertebra, below the spot where it receives the nerves of the legs, it sends off prolongations, the appearance of which has suggested the somewhat disrespectful name of horse-tail. In the upper part of the loins, where the nerves of the legs centre, a perceptible enlargement occurs, it then decreases, swelling out again at the lower part of the neck, where it receives the nerves. Lastly, it again diminishes in size, as it approaches the occipital opening, through which it passes into the cranium; but this passage once effected, the enlargement increases so much, that it is no longer recognizable; it then loses its former name, and is henceforth called the brain.

Such changes often take place in upstarts, who, when they become important personages, assume a new name. On this occasion, we have, to speak the truth, to do with a very great personage, so superior in his new rank to what he formerly was, that one may conscientiously adopt the change.

We are now going to examine it with the attention it merits.

CHAPTER XXVII.

THE BRAIN.

HERE we are in the manager's office. I forewarn you it is a somewhat dark place, but we shall see well enough for this once; we have only to make an inventory. I shall say nothing when we come to ransack the drawers.

You probably think that the best way to ascertain what lies beneath the skull will be to remove the lid carefully and look within. If you adopt this plan you will be disappointed; what you would find is simply a covering to that which lies beneath. You would only discover a grayish cap divided in the centre and furrowed by large zig-zag folds in all directions, which might even be mistaken for a portion of the intestines rolled up. This is not the place, then, from which to commence your inspection.

When we wish to examine the interior of a house we do not climb upon the roof, we enter by the door; that is what we must do now.

Suppose we glide in with the marrow through the occipital opening, we shall then be very well situated to commence our observations.

Here we are, then, immediately above this irregular mass of protuberances, of points, and bony knobs forming the base of the skull; and from a description of all of which I have hitherto recoiled, when studying this rugged part of the skeleton. As the brain is moulded

by the skull, or, to be more exact, the skull by the brain, you must already conclude that we shall have to encounter all sorts of irregularities.

Hardly has the marrow made its way through the entrance, than it begins to expand. It continues increasing so as to form a kind of rounded pyramid; this is, in fact, the name given to each of the two halves of this part of the marrow, for it still continues to be marrow, although it has penetrated within the skull. In this region it preserves its general type so distinctly, that a mistake is impossible; thus it is here called elongated marrow, or medulla oblongata, by anatomists.

It there receives one upon another, within a very small compass, seven pairs of nerves, which proceed from the tongue, the mouth, the ear, and the face. The service is far more active in this region than it is along the vertebral column; it is quite natural to meet with an increased number of the manager's advertising wires here.

I told you in my last chapter that the nervous fibres, coming from all parts of the body, continue to traverse the entire length of the marrow toward the brain. Arrived at the top of our pyramid, they there perform a curious evolution. Those coming from the right side of the body pass to the left, while those coming from the left take the right side. You will see later on the result of this crossing of the fibres, which the investigating scalpel of the anatomist has discovered far in the depths of the pyramid where it slyly takes place.

This sleight-of-hand trick accomplished, the great transformation commences.

The upper part of the marrow expanding to a very considerable extent, bursts forth to right and left, and becomes the cerebellum.

Put your hand upon the projection made by the back of the skull above the neck—that is the seat of the cerebellum, or small brain. It is really a kind of small brain quite distinct from the large one, beneath which it disappears when we look at the cerebral mass from above, and which has its own particular form as well, no doubt, as its own special function.

It has a furrowed or puckered surface, resembling that of the real brain, but the folds here are quite differently disposed. They have been compared to the leaves of a book. I own I have examined them very carefully, and can in no way trace any such resemblance thereto. Fold a dark-gray shawl very small, and gather up the folds so as to make a rounded buffer of it with a hollow in the centre, and then you will have something that will give you a far better idea of the appearance of the cerebellum than the leaves of a book, however crumpled they may be.

I advised you to choose a gray shawl, because the cerebellum is composed of this gray substance constituting the nucleus of the spinal marrow, but it is traversed in the interior by threads of a white substance, so arranged that when the organ is cut from above downward through the centre, a distinct regular outline of a leaf with all its fibres is discernible. From this design anatomists in a poetic moment gave it the name of arbor vitæ.

Must I say it, my dear child? Your cerebellum is very small, much smaller by comparison than mine, which ought to be about one-eighth of the total mass of substance lodged in my skull. I say about, because there is no fixed rule for it, and you can readily understand the impossibility of obtaining the accurate weight of any one portion of a living person's body. It is an organ that

requires time to mature, just as the bones do. It waits to begin its ordinary development until the time when we look for down upon youths' cheeks, and expect young ladies to become reasonable.

The cerebellum is divided into two equal parts. This being the invariable rule from the top to the bottom of the median line, I should not waste my time in again alluding to the fact, had I not some reason for so doing. These two halves are united underneath, by a large bundle of white substance which rests against the base of the skull, concealing what remains of the medulla oblongata, over which it passes, like the arch of a little bridge thrown across a stream.

The marrow as if taken prisoner, enclosed within a ring between the cerebellum which overhangs it and its uniting bundle, disappears at this point. For this reason, the bundle projecting beyond the cerebellum has been called the annular protuberance; but it has also another name, and one you will more readily remember, viz., the pons Varolii.

There are favored hours in science as well as in all other things. Happy he who succeeds in making useful discoveries. This Varolius, who has stamped his name under all our skulls, immortalized himself at a very small cost, with this bundle of the cerebellum. The discovery was by no means a very difficult one. In my last letter to you I spoke about geography. Varolius flourished in the sixteenth century, the period of great geographical discoveries in the human body as well as upon the globe. He lived at the time when anatomy was only in its infancy and its discoveries at their dawn, and thus had the good fortune to be one of the first who delineated a map of the brain, upon which he inscribed his own name, as invariably happens in similar cases. It is

however, a map as valuable as any other ; and when the progress of general instruction shall have placed every one in a position to see their way within the labyrinth of the brain, I do not know that I would exchange the honor of discovering the pons Varolii for that of the discovery of the strait of its contemporary, Magellan. Scientific men in the present day have no such good fortune to expect. The geography of the brain is complete or very nearly so, and discoveries there are as unlikely as in the Mediterranean Sea. It is true that in the time of Varolius, anatomical experiments were sometimes as dangerous as the expeditions of those intrepid navigators who made the tour of the world in mere shells of ships. Anatomical investigations might have brought their authors to the stake. It is said that the illustrious Vesalius, who placed the scalpel in the hands of Varolius, was obliged, while giving his first lessons; to conceal himself as if he had been a malefactor. The conservators of ignorance, in those days, raised the hue and cry of profanation ; and some of them may charge me with the same thing for having attempted. . . . . But we have gossiped enough on this point ; let us now return to the marrow :—

It reappears beyond the bridge of Varolius, in the form of two little thick cords, which unite and form a mass, the irregularities on the surface of which furnished a fine field for the play of the imagination of early investigators. They saw in them all kinds of resemblances which I need not allude to here, particularly as up to the present day, we have been unable to discover what is the exact part these hollows and elevations perform in the human machine, the outlandish names of which would teach you nothing.

The whole terminates in four small eminences, which

are designated optic lobes; the term sufficiently explains their use. They preside over the sight; and it is here that the principal branches of the nerve of the eye are united to the central organ; the nerve, I mean, through the medium of which we see; for in addition to this, the eye has other nerves to which it owes its exquisite sensibility and its variety of movements.

The region of the optic lobes is, we may say, the upper extremity of the marrow which stops here. We, however, have not quite finished with it yet.

Do you remember what I once said to you regarding the bone of the nose, that rudimentary vertebra which I represented to you as "the last effort of nature in its completion of the vertebral column" (see Chapter VIII., on the head and chest.) Well, the idea I wished to give you in that instance, finds a sort of confirmation here. There is also a last effort at construction in the marrow when it reaches its extreme limit. Two horns branch out from its extremity, of which they seem like a prolongation, and can you guess what they are? They are neither more nor less than the olfactory nerves,* which, terminating at the upper part of the nose, preside over the sense of smell.

Before ending in this rudimentary nasal vertebra, the vertebral column rises in an arch, thus forming the skull. The same with the marrow; before producing the olfactory nerves with their bulbs, it gives birth to the marvellous guest for which the skull has been constructed.

I have not given you the names of these two thick cords which spring from beneath the pons Varolii, the bridge of Varolius; they are called the peduncles of the brain. I conclude you have learned enough of botany to

* Olfactory, from the Latin word, olfacere, to smell.

understand the meaning of the word peduncle. It is what is commonly called the stalk, that by which the fruit is attached to the tree; but never peduncle bore fruit equal to that which grows here on the marrow. Whilst its lower part continues to thread its way distinctly along the base of the skull, the peduncle spreads itself upward, and projecting its fibres in every direction, loses itself in the expanded mass of the brain proper.

CHAPTER XXVIII.

THE BRAIN—(*Continued*).

It is a pity that for this once we must confine ourselves to a description of the brain! There are many subjects more amusing than this; nevertheless it may interest you to learn something about the formation of an organ which is, without doubt, the noblest if not the most essential of the whole body; that one in which resides—do not take it amiss—your little self; for were it to cease working, all that would remain of you would be a mere machine, unconscious of everything, even of your own existence. Your body may be considered as your house, but your brain is your chamber, your own private corner. You will not complain, then, I am sure, of the hurried glance we are going to take of it.

The brain being placed upon the median line, it naturally follows that, like the cerebellum, the marrow, and other portions of the body, it is also divided into two equal parts. Only in this instance, the line of partition is more strongly marked than elsewhere. The cerebral hemispheres—such is the name given to these two halves—are separated, the one from the other, by a deep furrow, which descends almost half way to the base of the skull. It is only at the base that they unite on a layer of white substance called the corpus callosum, or callous body, a name that I should feel puzzled about if called upon for an explanation. I fully understand—and most probably you do also—what is meant when one speaks

of a callous hand; but as for this callous body, which is nothing more than a thin, delicate slice of brain, I own that I know not for what reason it has been so named.

I spoke to you about the three vertebræ which are to be found in the skull. This division has its parallel in the brain, which is transversely divided into three lobes, as they are called; the anterior lobe, which is formed under the frontal bone; the posterior, under the occipital; and the median, which corresponds to the parietal bone.

To be honest with you, my dear child, very minute inspection is necessary to recognise, amid the numerous furrows visible on the surface of the brain, the respective limits of these three lobes; above all, that of the two last named; it being, between ourselves, a somewhat conventional limit. I strongly suspect that anatomists have taken the same liberty in the construction of their chart, as diplomatists sometimes do with theirs; with the best will in the world I have the greatest difficulty imaginable to see in the line which they have invented, anything which might be called a natural boundary or frontier. As to the line of demarcation on the frontal lobe, that is quite another affair. Nature has marked it by a fissure or furrow much deeper than the others; it bears the name of the Fissure of Sylvius. You must also bear this name in mind, for Sylvius, like Varolius, was one of those happy and fortunate individuals of the sixteenth century, who founded modern anatomy; but the former has the superiority over the latter, inasmuch as he was not the disciple but the master of Vesalius.

I have already informed you that the whole surface of the brain has the appearance of a grayish mass; the interior is white. Here we again encounter the two substances which I pointed out to you in the marrow; the gray and the white; only in the present instance their

positions are changed. We now find that the white substance which in the marrow covered the gray, is here covered by the gray. A thin layer of this gray substance extends over the entire surface of the three lobes, and may be compared to a species of bark, from which circumstance its somewhat singular name of cortical is derived. And now I must tell you, my dear child, that this cortical substance has the honor of being considered as the seat of intelligence, and it is not at all improbable that it may be so. After that, how can you judge people by their names!

The white substance which fills the interior of these two hemispheres is not a compact mass. You must have observed what large holes you sometimes find in your breakfast roll; a most unwelcome discovery to a very hungry child. Well, a similar vacuum exists in each of these two hemispheres, and one might truthfully exclaim, What wonderful economy Nature has employed in her arrangement of the brain! Most assuredly it is all wisely ordered for our good, else why should she have placed a passage of communication between the exterior surface of the hemisphere and its interior cavity, upon the walls of which the highly-favored cortical substance is continued. The intelligent bark—you understand what I mean by the expression—is thus allowed fuller scope for its development. From this circumstance you will also perceive how unsuitable the term empty-headed is, in the way we frequently hear it employed, to convey anything but a compliment. All of us, without distinction, have empty spaces in our heads; and were the brain a compact mass, it is to be presumed we should gain nothing by it.

The cavities of the two hemispheres, like those of the heart, are named ventricles. They are also called lateral

ventricles, from their being one on either side. Exactly at the base of the brain, underneath the callous body, is a third cavity, known as the middle ventricle; and lastly, the cerebellum has its own ventricle, communicating with the middle one by means of a kind of passage which, extending over the prolongation of the marrow, crosses the pons Varolii. And here the names of our two great anatomists are brought into contact. This passage of communication is known as the Aqueduct of Sylvius.

I could find you others were I to lead you over the whole brain; investigators have not been wanting in this locality. I must own I feel some scruples for having introduced you so far into such a labyrinth, in which people will perhaps tell me you have no business, inasmuch as no person has yet been able to discover the particular function each part of the brain discharges. However, I hope you will not blame me. Imagine yourself visiting some ancient temple, belonging to a creed no longer existing; with what curiosity and interest you would pry into its crypts and galleries, although ignorant of their former use. And are you not equally interested in this little living temple, into which the Spirit of the Almighty descends as each good thought ascends? Can you not survey its details with a curious eye, even though the meaning may often be as a sealed letter to you?

I have almost finished; there is only a tiny chapel to introduce you to, which might be designated the sanctuary. I hold to your making its acquaintance; its name is the pineal gland.

Immediately by the side of the callous body, and upon the same line, a little above the entrance to the aqueduct of Sylvius, there is a kind of little gray tubercle, quite isolated from the surrounding mass, and which appears as if it had been thrown there as an enigma to be solved.

Greek physicians, with Galen at their head, misled by its peculiar appearance, imagined this pineal gland to be the seat of the soul. According to their theory, the soul resided there, and guided the body much in the same way as a coachman manages his horses from his seat on the box. Two small white bands proceeding in the direction of the optic lobes, appeared to them fully to corroborate this theory, and were named the reins of the pineal gland. I should never have alluded to this fantastic idea, which like many others of its kind would now have been forgotten, had not a modern philosopher of note taken it into his head to revive the supposition, and append his own name to it. This was no other than Descartes, and when you are grown up, take my advice, and read his work called "Discours sur la Methode" in which our ancestors studied the art of reasoning. Thanks to Descartes, the pineal gland has had its palmy days, though unhappily they are passed away, and I truly think the soul would have found it but a poor lodging. Small stones, which medical men designate as calculi,* are often found in this gland. Bichat once found the whole gland transformed into one concrete mass, which by continuing to increase in size attained unusual dimensions. You must agree that in this instance, the soul of him who possessed this pineal gland would have been ill at ease.

Three envelopes of the spinal marrow are found at their post surrounding the brain; the pia mater lies immediately over the organ; the dura mater is placed next to the osseous walls without being attached to them; the spider web of the arachnoid is between the two. You can easily understand that the marrow in its transformed state,

* From the Latin calculus, a stone. From this the universal acceptation of the word calculation is derived. Roman children were always taught to count with pebbles.

and in a new home, could hardly be expected to have the same coverings as it possessed when in the vertebral canal. When a gentlewoman becomes a duchess, she requires new associates and an improved toilette.

With each pulsation of the heart, a considerable stream of blood is precipitated toward the brain almost in a straight line ; this part of the body receives a greater quantity of blood at one time than any other ; it is, moreover, the most sensitive, and the most readily deranged. A sudden rush of blood proceeding toward it from the great arteries would place it in imminent danger. Nature has provided against this disaster.

You have a little garden of your own, and you know as well as I do the havock a watering-pot makes among a plot of seeds, if you neglect the precaution of putting on the rose, which, by its multitude of perforations, converts the stream into a gentle shower. A somewhat similar precaution has been adopted here. Before penetrating the brain, the arteries employed to convey the blood are subdivided into an infinity of small canals, which, running along, interlace themselves on its surface, and thus, as it were, they shower out the blood, drop by drop. A multitude of small venous canals arranged in the same manner on their part pump out the blood, drop by drop, through thousands of thread-like veins as fine as hair, after it has served its purpose. Thus the circulation of the blood in the brain is effected by an endless variety of arrangements, the result of which is to regulate, in exact proportion, the departure as well as the arrival of the vital fluid. If the brain is the great instrument of life, the blood is its virtuoso ; a virtuoso whose caprices would be fraught with danger—if too fiery he would break the strings, if too indolent he would allow the harmony to be disturbed.

Now, if you search on the surface of the brain for the pia mater, that dense covering which held the marrow in the centre of the canal, it seems to have disappeared. You only perceive, in its place, the network of which I have just spoken to you, of small arteries and veins, scarcely held together by an imperceptible tissue which can hardly be called a membrane. It is, however, the self-same covering; and in order to satisfy yourself on this head, turn to the entrance of the occipital opening, when you will see that it has glided with its precious charge within the skull, and is for one moment recognisable in its passage over the elongated marrow; but it soon grows thinner, and at last, somehow or other, becomes annihilated by numerous invasions of small blood-vessels, before which it disappears. It is like a tender mother who sees her child in imminent danger, and confides him to the hand outstretched to rescue him.

Setting out from this point, the duty of immediate protectress, hitherto exercised by the pia mater, passes on to the dura mater, which in the skull attains an extraordinary solidity and thickness. Here, there is no vacuum between the dura mater and the other parts. It is true that the space is much greater, but it is entirely filled up by the cerebral mass, which slightly touches the dura mater, applied closely as it is to the walls of the skull, so that it forms a kind of periosteum to them. It only leaves them, in order to bury itself in the groove running between the two hemispheres; its powerful intervention being necessary to prevent any contusion resulting from the repeated oscillations of the head, and to support the occipital lobe above the cerebellum which it overhangs. You will find no difficulty in recollecting the names given to the two prolongations of the dura mater; they speak to the imagination. The first bears

the name of sickle, from its lengthening out in the same sense as the curve of the brain. It pretty nearly resembles the blade of a sickle. The second has been called the tent of the cerebellum, from being stretched over it like the canvas of a tent. There is also a third prolongation, which performs the same service for the two halves of the cerebellum that the sickle does to the two hemispheres of the brain, and for this reason it is named the sickle of the cerebellum; but this latter is of very trifling importance compared with the other two.

The dura mater forms so solid a covering, and adheres so firmly to the organ it is destined to protect, that the skull may be broken by repeated strokes from a hammer, without injury to what lies underneath. I ought to mention that I here allude to a lifeless skull, which has passed into the anatomist's hands, and the hammer is therefore wielded by a skillful operator. But this is quite sufficient to prove to you how closely and carefully the cerebellum is packed up in this dura mater, and what a small space is left to the liquid secreted by the arachnoid to be effused with impunity.

On this account, inflammations of this little spider web, insignificant as it is in appearance, so soon terminate fatally. Tightly enclosed between the dura mater and the pia mater, scarcely does it begin to secrete a little more abundantly than usual, than pressure is experienced on the brain, the action of which is immediately interfered with. The whole machine is thrown into disorder, and sometimes after the lapse of a few hours, life becomes extinct, to the no small grief and astonishment of the surviving friends. I hardly know, my dear child, how I had the courage to enter upon such a subject with you; it awakens in me recollections which send a shudder through my whole frame. Say nothing of this to your mother.

CHAPTER XXIX.

ANIMAL ELECTRICITY.

Let us go back for a moment, my dear child, to the "History of a Mouthful of Bread," which I took such pleasure in relating to you when you were much younger than you are now, and when we looked upon study as a mere diversion. We have now become more serious, and it is less amusing I know very well; but you learn more, which is the essential point; and this will always be the case as you advance in years. Your play-hours will be less numerous, but if you are good, believe me, you will be no loser by the exchange. The realities of life, when we come fully to understand their vast importance, are far, very far superior to the amusements of childhood.

I hope you have not forgotten the magic steward* I told you about in our earlier interviews, who distributes to the workmen throughout the house we occupy, our body, whatever materials they require, and whose inexhaustible pockets, continually replenished by the stomach, contain whatever is necessary to each individual organ. I also told you how in proportion as the constructions are effected, the materials for which are furnished by the blood, they disappear of their own accord, the old bricks making room for the new ones, and returning to the torrent which brought them. Later on, I explained the secret of animal heat, always kept up within us to the same temperature, by reason of the in-

* See "History of a Mouthful of Bread," p. 35.

cessant combustion of our own substance, and I related some of the feats of oxygen, hydrogen, carbon and azote, or nitrogen—"that wonderful quadrille of the aliments* of nutrition," which may be transformed at will. Now albumen, then fibrine, again casein, according as the dancers are grouped for the performance of different figures.

Remain perfectly still for one moment, give your whole attention to yourself, and listen to the life going on within. Do you not perceive a kind of general crackling which becomes stronger the more your thought is fixed upon it? This crackling continues through life, but we are so accustomed to it that we take no notice of it; nor would there be any object in our concerning ourselves about it, for we have no power whatever over it. Nay, on the contrary, if I may so express myself, it exercises a power over us—a supreme power; for it is no less than our physical life, the essential basis of all the others, speaking of what we are able to understand. In its depths are found intermingled, pell-mell, all those phenomena of construction, demolition, combustion, transformation of the elements of our substance from one to another, and all this, to give it its true name, is only one continued course of chemical action.

I made use of the term chemical action, in my note with reference to the pile. I was in a great hurry that day, and knew its turn would come, so I did not explain the term in its proper course. Moreover, chemical action is the very term I should have used when speaking to you of the union of bodies; therefore the thing itself is already known to you, if the word be not.

There is a secret power inherent in every atom of the diverse substances that we encounter. Scientific men

* See "History of a Mouthful of Bread," p. 232.

speak of it as affinity, a Latin word signifying relationship, connexion, in virtue of which they contract unions among themselves which are sometimes lasting, sometimes transient, according to their particular character, and also with some regard to the occasion allowed them of showing a fickleness of disposition; in other words, according as the inducement is more or less urgent to break off old alliances and form new ones. This going and coming of the atoms, clinging together, separating, forming friendships elsewhere again to be broken, is what is called chemical action, because the name chemistry has been given to the science that treats of these unions and separations, to turn them to our profit when a body, of which we hold the isolated elements, requires to be formed, or to rescue one element that only concerns us from among a multitude of others of which we have no need.

I spoke to you of all this at pretty considerable length, when I told you of the important services rendered us by the pile, and you must already have formed some idea of the important part electricity plays in all these arrangements. You have seen what an all-powerful agent it is, in building them up and in destroying them; but this only gives you one side of the connexion existing between chemical action and electricity. If the combinations of atoms are formed and destroyed on the passage of the electric currents, the atoms, in their turn, each time they change their combinations, produce electric currents. Thus it is that we are enabled to form the most powerful piles, by enclosing certain substances which act upon one another in an apparatus suitably arranged.

When these substances come in contact, their atoms mutually invite to movement, and they run away hither

and thither from their present dwelling, to form fresh alliances amongst themselves, or, in other words, to constitute a new body. This is the source of the electricity of the pile. Its currents maintain their energy as long as the dance is kept up ; let it begin to flag, and at once their power decreases. They disappear directly the primitive bodies, destroyed and brought to nought by the flight of their atoms, cease to furnish to the new combination the aliment necessary to its continuation. Suppose you found a pile which possessed the power to renew its own provisions of active substances as rapidly as they were destroyed, and also to disencumber itself of their inert products, the consequence would be, its operations would be carried on for an indefinite period, or rather, I should say, as long as the work of renewing and discharging should continue. If you have the curiosity to see a pile of this description anywhere, look at yourself, my dear child ; your own body is one.

You need not appear so much astonished. It is no cause for wonder that electric currents are produced in the pretty little pile that you form, seeing that this pile is incessantly and in every part at the same moment, the theatre of a myriad of chemical actions, one of which would suffice to produce a current, though it might be a very weak one. It would be cause for astonishment if the laws presiding over the change of atoms, throughout the whole universe, were found purposely suspended in your body, whilst all others, those of motion for example, exact the same undeviating respect from it that they are accustomed to do from the very stones. Your little body, then, is a pile because it is a chemical laboratory ; because it is, as I once before told you, a stove,*

* The fire that we make with our combustibles, being nothing more than a chemical action of an extraordinary energy, he who

and because it contains everything that we require to put into our piles when we wish to make them work.

Do not think disparagingly of yourself, if I appear to place you on a level with a scientific apparatus. He who formed the human pile is much more powerful than Volta, Bunsen, or Daniell; more powerful than all the illustrious pile-makers put together, and nothing that is imperfect issues from His hands.

In the next chapter I will tell you wherein lies the overwhelming superiority of the Almighty's work over ours. You have had quite enough to think about for to-day; fatiguing lectures should be brief.

If I have been unable to resist the great desire I had to explain some things which may be beyond your years, it is because they shed a wondrous light on what I formerly taught you, without being able fully to carry it out, from your not knowing anything of electricity. They reveal to you the true reason of this perpetual renewal of our substance, which lives only in virtue of its continuous destruction. Now you understand how the oxygen conveyed in the blood stirs up the organs it comes to burn, by inundating them with electricity, and I no longer require to teach you that we owe not only animal heat, but even life, to this internal combustion. As I proceed to explain motion to you, you will soon see what a close bond unites our life of nutrition with that of relation, the aliment changing into power as well as into substance; and that if the members are the servants of the stomach, the stomach is also servant to its

unthinkingly crams his winter stove, sets incalculable torrents of electricity in motion. If scientific men should one day take it into their heads to treat of the subject, they would very soon convince us of this.

members; not only because it nourishes them, but also because it helps them to walk.

Will you not candidly own that all this information is worth a little fatigue? And if your poor little head is wishing for a rest, thank me, but do not scold me.

CHAPTER XXX.

VOLUNTARY MOVEMENTS.

I STOPPED just in time with our last chapter. That there is within us a production of electric currents may be boldly affirmed from the simple fact that the contrary is impossible, unless, indeed, all the laws of the universe were reversed; therefore I felt I was right in speaking to you with confidence. I should, however, have been obliged to lower my tone, had I then touched on the question which is now to occupy us; viz., what is the action of these electric currents, what ends do they serve, and in what manner are they directed? It is not precisely suitable for one of your age, my dear child, to hear these mysteries discussed, and I do not know how to set about presenting you with an enigma, the solution of which has puzzled stronger heads than yours. My courage will be like that of certain soldiers on the field of battle, who march forward simply because their retreat is impossible.

Have you ever asked yourself what is meant by the will? No. I am sure you have not. It is one of those things children never do ask, because they never trouble themselves about it. The will is when we will a thing, you will most probably reply. I have many a time received this answer during the years that I have taught a young ladies' class, and it is as good as one of a more pretentious kind. Certain it is we have within us a something of which we are perfectly conscious, by means

of which we command our members to execute movements that are agreeable to us. To will does not suffice, however, in order to the execution of the movement; it would be far too easy if that were all: with the best will in the world, when our strength is exhausted we can do no more. Exhausted strength, what does that imply? There is, then, a power, which receives its orders from the will, and executes those orders whilst strength permits. If this power be not the electricity produced within us, by the perpetual interchange of atoms, I do not know where to look for it, and I shall soon have a grand proof to produce in its favor, in showing you the electricity from without incontestably exercising over our muscles the action which I conclude is exercised by that from within.

Now, here is the mystery!

Let your mother give you an order; you, as an obedient child, at once do just what she bids you; it never occurs to any one to express the least astonishment. There is no great difficulty in establishing connexion between your mother and yourself. You and she form, as it were, but one soul, and it is almost as if she had given the order to some part of herself.

When your father calls his dog—forgive the comparison, I will show you presently that it was necessary;—well then, when your father calls his dog, and the intelligent animal runs up to him, leaving everything to obey its master, this obedience creates no surprise in the mind of any one present. Great as the distance may be between the dog and ourselves, we are well aware, that it is not insuperable, and that the dog is an old servant that we are accustomed to. Nevertheless, the difference is great. If you were to order Turk to wash himself in the morning, and to soap his paws without helping him,

I think you would find it a difficult matter to make yourself understood. But it is unnecessary to say anything more about this.

Now, try in your turn to attract to you, without showing them any bread, the little gold-fish which are in the globe in the dining-room. I say try, for there is just a possibility that you may succeed. Fish are too far removed from us in the scale of animal life for the most rudimentary conversation between us to be understood; but they have eyes with which they can see us, appetites that we can satisfy; a species of understanding is, to a certain point, possible between them and us, and there is nothing very ridiculous in the idea of giving them an order.

But what would you say of a gentleman who should undertake to exact obedience from an oyster, to make it open or close its shell when ordered to do so? Such an individual would render himself liable to be sent to a lunatic asylum, to carry out his experiments there. Between the oysters and ourselves there can be no mutual understanding; any one must be devoid of reasoning who could for one moment suppose that there is.

Do not be impatient, you will see my meaning directly. If we are obliged to renounce the possibility of being obeyed by the oyster, how much more difficult must it be to obtain obedience from the shell. It is self-evident that inanimate objects cannot be subject to our orders. Did the idea ever come into your head as to the possibility of your controlling the rain that falls, the wind that blows, the heat that issues from a stove, or the electricity that runs along the wires of the pile? Well, it is exactly this last miracle that is performed by you, each time you raise your arm. You will something, and

the electric currents obey. Over what bridge is the passage of your will transmitted to them? Ask the Great Architect who has constructed it!

Very probably you are anxious to know what becomes of these docile currents, which ever appear ready to put the members in motion upon the first signal of the will, whilst the body is in a state of repose, and you ask me, Do they sleep when the members do? or are they shut up in barracks like so many soldiers in time of peace, waiting for the moment of action?

Certainly not; do not imagine such a thing, Nature has no warehouses stored with unemployed forces; she knows too well how to produce them the very moment she requires them.

You already know—it is learned soon enough—that when nations are not agreed among themselves, they have recourse to war in order to ascertain who is in the right; for this reason we have armies which are naturally more numerous during war than in a time of peace; this is what is called being on a war footing. A nation that knows how to conduct itself prudently keeps only the amount of armed force necessary to maintain order during the time of peace. Each man attends to his own business, without troubling himself about the government; indeed, so far as he is concerned, it might easily not be in existence. Instead of the national wealth being squandered, it accumulates, and proves an invaluable resource in days of strife. If war is declared, government immediately issues a call to arms, and armies appear to come out of the earth as if by enchantment.

Nature has adopted exactly the same arrangement in us.

During the moments of rest, the pile of which we have

been speaking is self acting, utterly regardless of the will, and only produces the exact amount of power that is requisite to keep up the work going on in the organs; a work which would suddenly come to an end, if these electric currents did not traverse them. It is here that the provision of substances accumulates, destined to be consumed, in supplying us with force, when an extra demand for it shall be made.

Movement is perpetual warfare; our arms war with all that we pull, all that we push, all that we lift, all that we strike; our legs war with every obstacle that lies in our path; the entire body wars with this ever-present enemy which we call gravitation, and which stretches us on the ground, the moment we cease to struggle with its influence. I daresay you never thought of all this, my dear child; but you might say to yourself as you raise your spoon to your mouth, that you and it are at war. You oblige it to ascend, while it would like to descend.

It is at such times as these that the government wakes up. As soon as its counsels have determined to open hostilities, the will issues its despatches, and in the twinkling of an eye the muscles are all ready for the combat, the blood suddenly rushes to the call, movement of the atoms is accelerated; the supplementary currents all at once spring up, and under their action the muscular fibre, just now motionless and extended, shortens, and contracts, carrying with it in its movement, the parts of the framework to which it is attached.

I have yet to tell you how these electric currents determine muscular contraction; how, at least, we are best enabled to represent their action. I shall reserve this explanation for our next meeting.

Before we part, I do not wish to allow so good an

opportunity to escape without explaining to you what sleep is, which is our great time of peace.

Movement has its charms for us, and so has war, it appears, for some nations. Still, when it is prolonged beyond certain limits, and has caused the country too large an expenditure of energy and men, for these are its component atoms, in vain government issues its despatches; the people, exhausted, lie down upon the earth and beg for sleep.

This is your daily history when you have given the reins to your electric current, and when your stock of destructible substances is exhausted. Your drowsy subjects turn a deaf ear to the call to arms made by the will. However valiant a warrior you may be, you must then beat a retreat before this overwhelming force, and you will soon find defeat await you on your pillow. We should not curse war as we do were it always to end thus.

CHAPTER XXXI.

VOLUNTARY MOVEMENTS—(*Continued.*)

A FRIEND of mine was talking to me one day of a motor power which he had been fortunate enough to discover. If you do not happen to know the meaning of the term motor power, let me tell you that the expression is applied to every kind of machine capable of producing movement.

Here in a few words is the discovery made by my friend; and after the little lesson I recently gave you on the subject of magnetism, I think you should be quite able to understand all I am going to tell you.

Picture to yourself a double rosary composed of small pieces of soft iron placed at short distances from each other yet united by flexible fastenings. A spiral copper wire is rolled round each of the rosaries, which can, at will, be immediately placed in communication with a pile in a state of activity. A very simple contrivance establishes a communication between the two wires, so that each rosary, in its turn, is embraced in the electric current.

You are aware that under these circumstances soft iron becomes magnetised. The little magnets, which are thus suddenly produced in the rosary subjected to the current, having their poles necessarily in the same direction, seeing that they are in a line, it follows that each north pole faces a south one, the extremities always excepted, and by reason of the law I before explained

to you, viz., that "bodies electrified in an opposite manner will always attract each other"—all these magnets make a sudden rush at one another. Again, imagine ten such magnets all placed in a line, an inch being left between each; directly their poles are united by reciprocal attraction, so as to form one unbroken line, your rosary will be exactly ten inches short of its original length, a very considerable difference, you will say.

Now if you arrange the two rosaries so that they can act in an inverse manner upon a rod of wood or iron, each chaplet will attract the rod in its turn; the magnetism in the pieces of iron being conveyed with the electric current from one to the other, and a see-saw movement of the rod will be established similar to that of the piston of a steam-engine at work. Hook the bar on to anything you choose, whether lever, bar, or crank, and it will work just as a piston does.

"Oh!" exclaimed I, as my friend concluded his explanation, "it's the human arm you have been inventing there!"

I do not pretend to say that my exclamation was perfectly correct. This is not exactly the arm of a man, but I am greatly mistaken if the movements of the human arm do not take place after this manner.

And here, my dear child, I think it advisable to repeat a remark I made to you when speaking of muscular fibre. I told you in an earlier chapter that "these threads, or fibres, look like a kind of rosary, the beads of which placed at certain distances from each other alternately shorten or lengthen the fibre according as they approach each other, or return to their original position."

One thing was wanting in my lesson at that time; it was the explanation of the alternate movements of the muscular fibre. This I could not give you then. Now,

without pretending to enter fully on the subject, I can at least give you an idea of the manner in which they are produced.

Whatever be its origin, it seems to me evident that when we will a movement, an electric current rushes from the brain along the nerves to the muscle intended to execute it, and there determines a flow of blood, together with the necessary chemical action. The beads of the muscular rosary must then become so many small magnets, each having its pole in the same direction, and attracting each other with a power proportioned to the energy of the magnetism transmitted, the muscle remaining contracted so long as this influence continues. It is thus on account of the peculiar electric condition of the biceps and the muscles of the shoulder that the forearm bends on the arm, and the arm on the body. If we wish to bring the arm forward, the cerebral current immediately changes its direction, transporting itself to the antagonistic muscles; these in their turn contract, bearing away the bone in a contrary direction; the rosaries of the opposite side, suddenly losing their magnetic influence, allow their beads full liberty as soon as they are abandoned by the current.

All this appears very scientific, does it not? and yet I have dispensed with all the mysterious parts in this game of electricity, which, for very good reasons, I have by no means fully explained. Whatever use you may be enabled to make of this partial explanation, it is sufficient to give you some notion of the wonderful way in which our muscles contract; and if you one day chance to see your mother's needle and scissors magnetized by repeated contact with her fingers, you will understand how it all happens.

Whilst we are speaking about fingers, I wish to call

your attention to something that you may probably never have noticed.

Open your hand and stretch out your fingers, then try to close the middle one, keeping the others fully extended. If you succeed, you are cleverer than I am. Although my whole will is concentrated upon my middle finger, I cannot master it. Every time I attempt to close it, all its companions move along with it, waiting for no order; nay, it is worse than this, for they move contrary to my order. The fault must surely be mine, for I have seen people obeyed under similar circumstances, and the middle finger close upon the palm of the hand, whilst all the others remained extended. It must be that the electric currents communicated to my hand by the instigation of my will are like so many disobedient servants following a routine, and being in the habit of moving in unison, refuse to act singly, whenever I am disposed to call on them to do so. Pierre Gratiolet, in the remarkable book which he has left us on "La Physionomie et les Mouvements d'Expression," gives the name of sympathetic to those movements which we are called upon to make simultaneously with other movements, and which the will does not always accomplish without severe discipline. He especially notices a child's first efforts in learning to play on the piano—the great difficulty it experiences in acquiring a perfectly independent movement with its two hands—the trouble and tedious practice necessary before it can play a scale so steadily, that the little finger of the left hand exactly coincides with the thumb of the right, and the first finger of the one hand with the third of the other.

This leads me to speak of the freedom of action in this little kingdom of arms and legs, over which you preside, although you are perhaps less absolutely its queen than

you would naturally suppose. Besides this voluntary movement, which is entirely subordinate to your will, there is also a mechanical one, which the machine executes without any intervention on your part, just as a well-trained animal may be taught what is expected of it, and to attend to its duties without being constantly guided to them by its master. In the act of walking, for instance, when you are absorbed, I will not say in your thoughts, though that will come in good time, but in one of those interesting conversations you carry on with your little friends, how frequently you dispense with this voluntary movement, and substitute the mechanical one! Your will is all the time occupied with something else, yet your legs continue to carry you along of their own accord, without a false step. Be honest now, and own that you would be sorely puzzled if the whole management of walking was left to your own guidance. You control your steps much in the same way as three-fourths of our kings declare war; they give the signal for it, but it is carried on without their assistance.

These habits, which our agents adopt, and then, after a time, carry on without any help from us, are not the least of the mysteries found in our organization. I can bear testimony to a very tiresome trick my hands are guilty of, and which I have been unable to cure them of hitherto. Every evening, before I undress for bed, I am accustomed to wind up my watch, which is all very right and proper if you want to know what o'clock it is when you rise on the following morning. Now when I have occasion to change my clothes during the day, no sooner do I unhook my watch-chain from the buttonhole of my waistcoat, than my hands, taking advantage of my thoughts being occupied with something else, stealthily

set to work, and before I know what I am doing, the watch is wound up. Who is the agent in this instance? Am I the agent? Did my hands perform the deed? Certainly I could not have done it, for I was not thinking of it.

Now observe, that the watch is not wound up by one single movement, by one emancipated muscle which slyly contracts itself; there is a whole series of complicated movements, which I need not enumerate. You have but to call to mind the working of your fingers as you wind up that pretty little watch of which you feel so proud. But, compared with what I have to tell you, all this is very insignificant.

How long and how patiently your mother devoted herself to teaching you to speak! You can neither recollect nor realize the labor it cost her! You will one day know it, if you should have a child of your own whom you would teach to say mamma. If you take notice then, you will see that in order to pronounce each of the syllables, of which words are composed, the tongue and lips must assume a variety of positions successively. The lips open, then close, are pressed together, and advance, whilst the tongue strikes against the palate at one moment, leans against the upper teeth at another, or gently places its tip just within the lips. Added to all this, each muscle of the chest, throat, jaws, cheeks, and even of the nose, has its peculiar work which is constantly changing. In order to pronounce the simple word confiture, which seems to come quite naturally from your lips, you have no idea of the number of little muscles that are at work at the same moment, and the various manœuvres they have to execute. Thus you see the first words little children utter are composed of one syllable twice repeated, as papa, dada. It is so difficult for them

to enunciate at first that all they can do after having succeeded in pronouncing a syllable, is to recommence; the fatigue of passing on to something fresh would be too much for them.

Tell me, if you can, what is become of all the effort each word cost you as you learned to stammer it out? How is it that you now can prattle away for hours together without a pause, just as if the words were so much running water? It is simply because the education of this set of servants is completed, and they cease to cause you any anxiety. No matter at what speed the little tongue runs on, each word finds the muscles at their post, and the rapidity of thought to conceive a sentence is frequently surpassed by that with which it is pronounced.

In all this, may we not ask, as we make use of our tongues, To whom then does belong the honor of speech? I answer: To our intelligence; because, although the mechanism of words is claimed by the muscles, we must in the first instance furnish the ideas they express, which is evidently a higher power. But I have something more extraordinary yet to tell you.

I know a very old lady who, when a little girl, was taught a prayer which she repeated, as too many children are in the habit of doing, without once thinking of the meaning of the words. Let me observe, in passing, that to offer mere lip homage to our Maker, in which the heart takes no share, is but mockery. You may as well imitate the Tartars, who stick their prayers upon a roller and turn it with all their might, exhorting it to intercede for them. God, who looks into the heart, sees and knows who really desire to honor Him, and He knows how far this old lady acts up to what she has been taught; it is the intention He considers. Strange as it

appears, though she has quite forgotten the prayer taught her in her childhood, for words to be retained in the memory must have some hold upon the mind, yet when the desire suddenly seizes her, this old lady will go through the prayer by rote. Perhaps you have sometimes heard of travellers, who, losing their way at night, and despairing of recovering the beaten track, will throw the rein upon the horse's neck and trust to its guidance. This is precisely what my old lady friend appears to do; she shuts her eyes so that nothing may outwardly interrupt the performance of her duty, and fearlessly yields the rein to the muscles which preside over speech. These muscles have performed their work so repeatedly that they are easily set in motion, and the prayer which its mistress has mentally forgotten, the lips are made to utter mechanically; but I must admit that the prayer is blurted out, and if she is interrupted, all is lost. Who after that would quarrel with muscles which perform such a wonderful feat of memory?

Assuredly, if these are also voluntary movements inasmuch as the will gives an impulse to the speaking machine, you must own they have reason to boast of their independence, and I leave it to philosophers to point out the director of this assemblage of muscular contractions which rapidly and blindly succeed each other in the same invariable order.

The question is far beyond us, and I prefer making this occasion profitable by exhorting you, whenever you commit anything to memory, to store the words well in your head, and not on your lips, as certain young ladies of my acquaintance do, who read their lessons over as loud as they can that their muscles may be well exercised for the recital. How will you make any progress by teaching words to your muscles? What are they to do with them?

CHAPTER XXXII.

THE CEREBELLUM.

I ADVISED you at the close of the last chapter not to teach your muscles any words. It is not exactly the muscles which learn, although to speak the truth, it amounts to the same thing; they seem to learn. In order to acquaint ourselves with what goes on in their province, we shall require to take a little tour through the capital, or in other words, pay a visit to the head, since the word capital is, as you probably know, derived from the Latin caput, signifying a head.

I have already informed you, that this invisible director, who imparts impulse to the muscles, and holds in his hand all the telegraphic wires by which the orders of your will are transmitted, resides in the brain. You are this director. To call him by his proper name, he is your own little self, and he is incapable of performing any act without your knowledge.

Now there is also a sub-director, in close proximity to this director, through whose hands each wire must pass before it reaches its destination; he is the real regulator of each manœuvre the muscles perform, and this is no longer you; he works in the dark without letting you into the secret of his acts and gestures. What he is, no one knows; his whereabouts only is known; for he resides in the cerebellum and its dependencies, or, to be accurate, in the pons Varolii and around the Aqueduct of Sylvius. I hope you have not lost sight of the little

chart we made of the brain. Order and the progress of movement are regulated in this department; we have a most beautiful proof of this, or a horrible proof, you may feel inclined to call it, when you know the facts, and you are at liberty to call it so if you please.

The species of study which I intend to bring before your notice first suggested itself, at least on a large scale, to the mind of a French physiologist named Magendie. It is a barbarous study seemingly, for it has caused thousands of animals to be cruelly put to death; but where science is concerned, savants look upon any leaning to the side of humanity as only puerile. Are they justified in this? It is not for me to decide. Every one has his own conscience, let that be his guide.

I borrow the subjoined facts from Milne-Edward's " Cours de Zoologie."

If, after opening an animal's skull, you cut a small portion from off the base of the brain, situated in the vicinity of the cerebellum, and which is known as the corpus striatum or striated body, though for what reason I cannot say, the animal suddenly darts forward as if carried away by an irresistible power, and it runs on and on until some obstacle presents itself in its path, or it stops through sheer exhaustion, but backward it cannot go, for it is deprived of all retrograde movement.

Again, if a section be made simultaneously, on each side of the cerebellum, or pons Varolii, the result will be exactly the reverse; in this instance the animal makes an equally sudden rush, but the motion is retrograde, and according as the animal is a quadruped, a fish, or a bird, it will walk, swim, or fly backward, having lost all power to move forward.

Lastly, if an incision be made in one side of the cerebellum, or pons Varolii, you will witness a no less singular result; the wounded creature will revolve upon itself; if the incision has been made at the right side, the movement will be from right to left; if on the left side then the movement will be reversed; and so rapid has it been in some instances, that more than sixty revolutions in a minute have been remarked.

From all this it may warrantably be concluded that a despatch office exists below the apartments of the will, whence orders are issued to every part of the body, and that it resembles an ordinary government, inasmuch as, to enforce obedience, the offices must be intact. Nay, the case is even more serious; one false despatch issued by the subaltern sets all in motion, but precisely in an opposite manner to what is intended.

We are now in possession of a key to these movements, which are executed either without the will being consulted on the subject, or in direct opposition to it. We shall also find some analogy to this as in government arrangements, in what is called office routine.

There are certain old affairs long forgotten by the head of the department, the papers connected with which are in the repositories of the subaltern, and which he, on a simple order being received, terminates mechanically without the aid of his director. This is the story of the old lady and the prayer she learned in childhood to repeat by rote. You see how little there is to boast of, if, when you learn a lesson, you bury it in the subaltern's repository, never letting it reach the master's eye.

This is not all. Nobody is more obstinate than an office-clerk. What he has been long in the habit of doing, he *will* do, and not even king or emperor would succeed in making him depart from his routine without

immense difficulty. The orders may be given, yet the clerk still mechanically pursues his accustomed course. The clerk of the cerebellum is every whit as obstinate as his compeers. You wish to move one finger only, or to make one particular finger move in concert with another ; this is not his general habit. He lets you issue your commands, but he forwards his dispatches in the direction familiar to him. And thus it is, my little friend, that he sets you at defiance without your perceiving it, and even sometimes when you do perceive it.

An industrious and determined master will nevertheless overcome these routine difficulties, but only by repeated efforts on his part. Even you must acknowledge how fast your once undisciplined fingers are getting under your control ; they now find their way on to the right notes on the piano, without noticing who their companions may be. You are not obliged to be so constantly on the alert. Routine exists here, but it is a good form of routine instead of a bad one. In this lies the grand secret of good government.

It is nevertheless necessary, however determined we may be, that the offices be in good condition, if we wish to be obeyed ; for otherwise, with the best *will* in the world to go forward, we might walk backward, or even turn round and round, which would be still more disagreeable.

You, no doubt, consider yourself exempt from all these disagreeable mishaps, satisfied as you are that no investigator of science will ever take it into his head to make incisions in your cerebellum, that he may ascertain the effect they would produce. Who can say, but that among some of the people to whom you relate what I have just been saying, you may not encounter some, who, for the sake of the secrets they will divulge, will look upon these experiments as quite justifiable? If so, undeceive your-

self, my dear child, and let us caution lovers of science against too hastily coming to the conclusion that the end justifies the means. Nature deals pretty severely with us, and we already know all we care to know about these operations without the additional pangs inflicted by the vivisectors.*

Now and then we have it in our power to report very extraordinary instances of irregular movement resulting from some injury to the cerebellum. Among other examples mentioned in my books, I find that of a poor lady who was more seriously affected than any of the animals experimented on by the scalpel. Her limbs, owing to the equilibrium between the extensors and flexors being disturbed, bent without any possible resistance on her part, so that she used to fall down in a heap, and in this position she might be seen turning round and round utterly powerless to stop herself. Flattening or shrinking of the cerebellum was discovered after death.

Now, I have told you quite enough about this impertinent organ, which we may well imagine is placed where it is to stem the pride of little people who think themselves masters over their own bodies. Let me give you a word of caution, not to be astonished at the striking similarities between our interior government and those of human societies, resemblances which have just occurred to me while endeavoring to make you understand the part which the cerebellum performs in our economy. A society is like a man on a large scale, it tends by natural inclination to organize itself on the same plan as the human organization. I must have told you this already, but I will make it plainer than ever to you in the next chapter.

* Vivisector is the name which those who experiment on living animals give themselves.

CHAPTER XXXIII.

THE NERVOUS CENTRE.

We are now come to the delicate part of our explanation of movement. Whether cerebellum or cerebrum, it is assuredly from the entire cerebral mass that the electric currents determining muscular contractions radiate; but where are they produced?

This is a question well worthy of investigation, for here the will has no control. Chemical agency is as requisite to create an electric current in the human pile as in any other, and it would be impossible to produce one by a simple act of the will.

Encephalon is the common name assigned to the entire nervous mass lodged within the skull. Beyond a doubt, it is in this mass, in which it is natural to suppose the largest amount of electricity is produced, that the greatest quantity of blood is found circulating, and the brain in particular is specially adapted by nature for this arrangement. All this I told you when speaking of the pia mater. Besides, the soft and delicate nature of its substance must give free scope to the movement of molecules, which to all appearance takes place more rapidly here than elsewhere.

It would seem natural, at first sight, to expect that the will would here meet with its required agent ready made to its hand. Now, absurd and presumptuous as some persons may think me, I venture to assert that this is by no means the case.

The cerebral electricity never travels to any great dis-

tance for the purpose of compelling the muscles to contract; it may rather be likened to some stately dame who has much higher functions to perform, and who executes them without moving from the spot. I feel it busily at work in my head at this very moment, while taxing my ingenuity to give you a clear idea of what I do not too fully understand myself. Of this working I am convinced, because I am alive to the fatigue now present in my head, and also because of the superabundant flow of blood to that point, similar to what takes place in the muscles when they are in exercise; so great is it, that in spite of a lighted stove at my side I am suffering from cold feet.

To work one's brain, is an expression which presents itself to the mind of the most unenlightened, so vivid and universal is the physical sensation resulting from the incomprehensible act of thought. If I have not occasionally been afraid to make your brain work, my dear little friend, it is simply because intellectual education is most important at your age, and also because exercise strengthens all the organs equally, the brains which reflect—stop a bit, where does reflection take place?—as well as the arm that is required to saw the wood. If the amount of electricity expended by muscular movement were produced in the encephalon, then fatigue would be experienced in that point, just in the same degree as the expenditure of electricity, resulting from intellectual labor, is felt there. Now, when you have been walking all day, and the entire body succumbs, one single part of it remains insensible to fatigue; it is the head, or rather what is within it, the encephalon, for the muscles which retain it in its place are subject to the laws of other muscles; and in this instance, therefore, they participate in the general fatigue.

We must search elsewhere, then. Suppose we return to our comparison of a government.

Have you ever heard any one speak of what are termed Crown lands? in other words, property, the entire proceeds of which are appropriated to the personal necessities of the sovereign. I should be disposed to look upon the encephalon as being our Crown lands. The personal revenue of him who governs is always, as you know, far greater than that of other people, hence the frequent disputes as to who shall govern.

Besides all this store of wealth, a tax is levied throughout the country which goes to government, to be returned, under its direction, to those parts of the country which require common aid. Do not let us forget that a constant warfare is going on on this subject of movement where we are; it is a state of war we are speaking of in which the members of a society ought to aid each other in fighting the common enemy. Those, of course, who are immediately engaged in the struggle will be called upon to suffer the greatest personal loss. Government receives with one hand what it gives away with the other, and by this method cannot be ruined.

Such is the idea I form of these bountiful supplies of electricity distributed by the encephalon among the muscles which are called to the combat. I will not undertake to explain them to you as I did the currents of the voltaic pile. We are in the presence of too complicated an apparatus, the working of which is concealed from our investigation, and the electricity developed there has a character peculiar to itself, differing as widely from its namesakes in the inanimate world as the action of the magnet does from that of the electrical machine. But the results are there. It seems to me quite impossible that things should take place otherwise.

Whatever proceeding Nature employs here, there must of necessity be a continual circulation of electricity carried on between the provinces and the capital, and *vice versa.* During sleep, when the body is completely at rest, and when there can no longer be any question of muscular contraction, the electric tax paid to the nervous centre has its natural destination; it returns in a quiet and uniform current, determining, everywhere on its passage, the chemical actions which have produced it, as does the current of the pile, and in this manner life maintains itself in our bodies until the substances capable of producing electricity fail, or the circulation in the apparatus becomes interrupted whether by the occurrence of an accident or through exhaustion.

This interior service necessarily continues throughout life, inasmuch as it is life itself, and we may compare it to what we call public service. Postal communication for example, which is always going on, and, because essential to social life, must be maintained alike in time of peace or of war. In time of peace the taxes are light, there is not so much to provide for then, and this is, as I have told you, the time to economise. With the renewal of hostilities or of movement comes the war-tax, demanding those extraordinary contributions which wear the body out in a very brief space of time, and forcibly compel it to take refuge in the economy of sleep. When war is going on in any country, those provinces that are its theatre are naturally more speedily exhausted than any others; and so it is with our muscles, they can only endure local expenditure of contraction for a certain length of time. But the general expenditure is not the less felt everywhere; and if you compel any single member to work too energetically, lassitude will, after a time, pervade the whole body, because the other muscles have

been overtaxed on its account. If you pay attention to them, the involuntary contractions which then agitate them are quite sufficient to warn you that danger is impending. Thus it was that Russia finished by exhausting herself, in directing all her forces to the Crimea when Sebastopol was taken.

From all this we may conclude, that movement must be suppressed in any member when its communication with the nervous centre ceases, or when the centre becomes inactive. Every observation which has been made is in accordance with this conclusion.

Let us proceed to establish the first point.

The spinal marrow is the grand means of communication between the capital and the provinces; it has given vivisectors, they say, great opportunities to demonstrate scientifically, as they call it, a fact which the military hospitals, without speaking of others, teach us only too well. They sliced off small pieces from the spinal marrows of mammiferous* animals, commencing with the lower part, and always found that the movement was proportionably weaker in those muscles supplied by nerves issuing from below the section so made, and which had consequently been cut off from all communication with the centre of impulsion. The experiment was easily made. It never fails when a head falls beneath the axe of the executioner. The entire body becomes inert by one blow, because the executioner has commenced at the upper part of the spinal marrow.

But it is not requisite to slice the marrow above any member in order to destroy movement there, for the same result may be obtained by cutting the nerves which preside over the contractions of the muscles in the vicinity of the marrow.

* You will see farther on why I select mammiferous animals only.

This requires a few words by way of explanation.

You probably recollect the two little holes pierced at the interlacing of each vertebra; the one to the front, the other to the back of the column, and when the nerves, after separating into two perfectly distinct cords, effect an entrance into the vertebral canal. I called your attention at the time to this division of the nervous fibres on their approach to the marrow. The moment is now come, as I told you it would, for me to teach you what there is beneath it.

When speaking of the circulation of the blood, we noticed that it travels through a double system of canals; the veins bringing it from the extremities to the heart, the arteries carrying it from the heart to the extremities. The encephalon is a species of electric heart, if I may so express it; it is the point of arrival and departure to a double system of fibres; the one set conveying information, and probably the tribute of the life of the body to it; the other taking back its orders, and the amount of strength necessary to execute them. To carry out our comparison, they are to our government what the civil and military agents are to others.

These two classes of agents, after mixing together during their passage through the nerves, suddenly diverge when they reach the high road of the capital. Just imagine a regiment of soldiers walking pell-mell amongst a crowd of civilians. As they approach the town, the drum beats, and in the twinkling of an eye, the soldiers are in line, each man at his place; the troops on one side of the road, the crowd on the other. This is exactly the way in which our nervous fibres act. The military cord, or that of movement, penetrates the vertebral canal by the front entrance; the civil cord, or that at the head of the inquiry department, enters by the

back door, after which they continue their separate paths toward the encephalôn, gathering up, on either side, as they journey along, the bands of comrades ejected from each entrance before which they pass; and this is the way the two large cords are formed at either side of the spinal marrow, as I pointed out to you before, to the right and left of the median line. Each receives one kind of nervous branch only, the anterior cord, or that to the front, the fibres of movement; the posterior cord, or that to the back, the fibres of sensibility; consequently they share the general office of transmitting despatches throughout the body. Do you recollect the little dog biting your leg, and the kick you gave it for doing so? Well! pass your hand over your vertebral column; it was by means of the band of marrow next your hand that the sensation of the bite reached you, and it was through the internal or anterior band that the order was transmitted to your foot.

I have tried in vain, my dear child, and am sorely indignant, that I cannot avoid speaking to you of certain revelations made by the scalpel, which, while enriching science, have dishonored it, as is ever the case with ill-gotten wealth. They abound here with a superfluity that is truly revolting, and which would, I am convinced, have been considerably lessened if those to whom we owe them knew that on their return home every evening a little girl would be waiting to embrace them, and oblige them to give an account of how they had passed the day. As I have ventured to speak to you upon these, naturally, very interesting subjects, it is only fair that a few examples should now follow.

A Scotchman, Sir Charles Bell, the man who, of all others, has perhaps shed the greatest light on the functions of the nervous system, and who, according to the

opinion of a competent authority, M. Longet,* has in this department made the greatest discovery of modern times, recoiled from inflicting torture on the living animal for the purpose of wrenching from nature the hidden mysteries of life. The scientific glory which this man of rare genius and accurate observation acquired is untarnished by ferocity; and I must further say, to the honor of England, that whenever her physiologists desire to pursue their cruel investigations, implied in vivisection, they go to France for the purpose, not daring to attempt them in their own country. Charles Bell operated upon rabbits immediately after they were killed, and profited as much as possible by the small remnant of vitality existing in their still palpitating organs. We have scarcely any right to reproach him for so doing, as we do not scruple to kill these little animals for our own eating. Unhappily, though his demonstrations are very practical, they would involve explanations that would lead us too far into the subject. His successors, who were less scrupulous, have made experiments which require no explanation; and as it will sufficiently answer our purpose, I will relate one of them only, which was performed by a German named Muller, in the year 1831, twenty years after Charles Bell's discovery had been made public.

He took a frog, an inferior animal that possesses great tenacity of life; a mammifer would have died too soon under the operation to have allowed him sufficient time to observe it at his ease; and near to the spinal marrow he cut a part only of the three nerves communicating with each of the hind feet; he cut the anterior branches at the left side, and the posterior at the right; this rendered the left foot incapable of motion, whilst it retained

* Longet, Anatomie Comparée du Systeme Nerveux.

the sense of feeling. Means were not wanting to ascertain the certainty of this fact; the right foot became perfectly insensible and incapable of motion. Assuredly this experiment was sufficiently satisfactory, and did not require a second trial.

Sensibility and movement disappear at once in a member when we cut the nerves below the point where the two classes of fibres separate, the whole nervous supply being thus simultaneously arrested. The government is perfectly ignorant of whatever may occur afterwards, and can no longer enforce obedience. It has been isolated at one blow from its clerks and soldiers.

Lastly, we can, if we please, separate without touching the nerves, either the first or the second class of fibres, simply by making an incision in the spinal marrow above the limb, either in the posterior or the anterior portion of the cord. Here, however, the separation of the fibres is less certain, and, by dint of repeated experiments, it has finally been ascertained that contradictory results sometimes follow. It would appear that soldiers and civilians fraternise on the confines of the two bands, and here and there, on the journey, each side contains some deserters, and this capricious exchange somewhat baffles research. But what can be the use of so determinedly pursuing a few vagabond fibres existing within these poor creatures, the presence of which on forbidden ground cannot possibly alter the grand law discovered at so little cost? What can justify needless cruelty, when we have not exactly a right to absolution whilst practising, for a desirable object?

But, enough on this subject. At the commencement, my intention was not to speak to you on these matters, but my wish to find fault has superseded my resolution. It is before the tribunal of women and children that

questions of this nature must be decided. Men are apt to accept all kinds of good excuses which would not satisfy you.

Let us next see what happens when the action of the nervous centre stops.

CHAPTER XXXIV.

THE NERVOUS CENTRE—(*Continued.*)

HAVE you not sometimes suffered from those unpleasant dreams in which you distractedly flee from an indefatigable enemy, and try by a thousand ineffectual efforts to drag your legs along, when all the time they refuse to stir? If you can call to mind the wretched state of feeling into which this apathy of your members plunged you, by so reluctantly attending to your urgent entreaties, you will be able to form some idea of that terrible malady known as paralysis.

Paraluo, in Greek, signifies I untie, and paralysis unties those mysterious bonds within us which unite the electric current to the will.

This imaginary paralysis of our dreams is accounted for by the general drowsiness of the encephalon, the base of which continues in a lethargic state, after the imagination, awakened in the upper part of the brain first, has aroused the companion at its side, namely the *will*. The government, disarmed and incomplete, if I may so express it, but partially aroused from its torpor, vainly struggles to exercise its authority, and hence the positive sensation of refusal to obey, which is so well known to us under the form of nightmare. Imagine a monarch presenting himself to his people, and attempting to issue his orders in his night costume, unattended by police or soldiers! Such is the sleeper, and such the paralytic.

The will, when strong or over-excited, sometimes succeeds in enforcing obedience under any circumstances, and by its strength will shake off either sleep or paralysis. You can readily understand that the power of the will is not equal in all; it may differ in strength as do kings, but there is no absolute rule for this. It is difficult to picture Louis XIV. exercising any influence over the people, without the red heels to his shoes and his wig; it was quite different with regard to him whom the soldiers called "The Little Corporal," and who was not less imposing, but rather the reverse, in his gray riding-coat than under his imperial mantle adorned with golden bees.

It is related of Semiramis, the great queen of Babylon, that as she was one day engaged at her toilette, somebody suddenly told her that the city had revolted. She rushed furiously from the hands of her female attendants, and half-dressed and with her hair in disorder, she restored tranquillity with no other accompaniment of royalty save the energy of her speech and the flash of her eyes.

There are several instances on record in which a sudden fright, or outburst of excitement, has caused the will, of its own accord, to resume the reins it had before allowed to escape it; and paralytics have been known to recover the use of their limbs in a moment. This happened to the lame man whose history is so well known, who, lying upon his couch when a fire broke out near him, was so terrified by the sight of the flames, that with one spring he jumped up and ran off.

With regard to sleep, I once had a friend who had power over his dreams when they became too painful, and who by an impulse of his will could emerge from the paralysis of nightmare. Singularly enough, this

faculty, which is not without its value, was a recent acquisition, observed when his character became formed. He had no influence over his sleeping phantasmagoria until he had learned to control the actions of his life.

You also, my dear little girl, must have assisted at this struggle between the will and paralysis more than once, and I should be very much astonished if you are ignorant of what it is.

In the morning, when it is time to rise, has an idle fit never taken possession of you? Try it to-morrow, just to see, and take special notice of what occurs. All is awake in the brain, where the faculties are at work as if in full vigor, more even than at other times, because then all the powers of life are employed in their behalf. The will is also at its post, but it is undecided and listless; it feels as if it were hovering beneath the top of the skull, and it is not the desire to get up which is wanting. Unfortunately, there is a weight at the nape of the neck which fixes the head to the pillow; this is the base of the encephalon, the cerebellum, and its appendages, the torpor of which is not yet shaken off; the clerk has not yet opened the office. At last a great shock from the will forces the door open, the business of despatching orders immediately commences, the body which was lying paralysed now holds up its head, and life begins anew. All depends upon this opportune shock. For this reason it is a very easy matter to rise when there is some pleasure in prospect toward which the will bends. An excursion into the country, for instance, or the pleasure of being useful to your mother, ought to be sufficient stimulus were you always reasonable and dutiful; but as little people are not invariably so, I am going to give you a receipt, by following which, you will more readily overcome this sleepy clerk. Raise

your head first, a very little will suffice, the effort required is not great; by this means the office is shaken, and the clerk at once compelled to bestir himself.

I thought, my dear little pet, that by placing before your eyes an example so familiar to you as that of sleep, I should render the phenomena which accompany the interruption of the action of the nervous centre to the point of sight of the movement more readily intelligible to your comprehension. And now we must enter a little more in details.

The suppression of nervous energy seen in paralytics may be considered as a partial and permanent sleep, most frequently following on cerebral congestions. This is the term* applied to those sudden rushes of blood which inundate the encephalon, for which we cannot always give a reason, and which derange its action when they do not immediately arrest its work and produce death, or at least disorganisation of its tissues.

A strange phenomenon is sometimes observable in these circumstances.

I hope you recollect the median line dividing our body into two similar halves, which are joined together at the middle, like the two halves of a walnut shell. Sometimes after the disturbing flow of blood has subsided, it happens that only one of these halves is rendered torpid by the shock it has received from the blood, and the muscles on the one side are still alive, while those on the other side are dead, so to speak. Perhaps you may some day meet an unfortunate individual painfully dragging along the dead half of his body by the help of the living one. If you see that his face is all drawn to one

* They are also called apoplectic strokes, and apoplexy, two words with the same meaning, the second signifying in Greek a blow or stroke.

side, you have the reason fully explained here. The muscles of the face are marshalled in pairs throughout the length of the median line, toward which they all centre, as so many combatants equal in power, producing equilibrium. The equilibrium is suddenly disturbed, if one of any of the pairs of the wrestlers occupying either the right or left side is struck by death ; its surviving antagonist drags the powerless muscle over to its side.

It is by a similar disturbance of the equilibrium that the median line is so horribly displaced in children who make grimaces, who amuse themselves by distorting their features, lest they should grow up too good-looking ! but the *will* is the culprit in these cases. It renders the contest an unequal one by sending a reinforcement of electricity to one of the two bands ; and they who make faces would be rightly served, if, by dint of being contracted for no cause, the muscles of the privileged band* were to acquire the habit of it. You know that the muscles very readily acquire habits which they afterward retain, in spite of our efforts to cure them. Let me advise you to tell this story to your little cousin, who, if he continue, for sheer amusement, to disturb this precious equilibrium, so wisely established by Nature on the two sides of the median line, may one day find himself with the face of a paralytic.

Having settled this point, we will now return to those misfortunes which occur in spite of ourselves.

You may probably already have forgotten it, but there is a detail I pointed out to you when speaking of the species of rounded pyramid which the marrow forms after its entrance into the brain. Having reached the summit of the pyramid, if you remember, the nervous

* It is almost always to the side which they first distort that the faces of children turn who indulge in grimaces.

fibres that are collected there from all parts of the body decussate or cross each other at this point. Those coming from the right side of the body pass over to the left, and those from the left pass to the right. You will see by and by, I then said to you, what is the consequence of this interlacement or decussation of the fibres, which the indiscreet knife of the anatomist has revealed in the thickness of the pyramid where it takes place slyly. It is now the moment to explain this consequence. When paralysis manifests itself to the right of the median line, its seat is sure to be in the left half of the encephalon. If it betray itself in the left side, then the right half of the encephalon is the disordered part.

This is not all. I told you in my last letter that we have two systems of nerves—one for movement, the other for feeling—and that we can, at will, render a member powerless or insensible according as we cut the motor or the sensitive cords. Well, sometimes it is one, and sometimes the other of these two systems, which ceases to act after an apoplectic stroke followed by paralysis, according as the springs have been damaged in the cerebellum or the cerebrum ; at least we have the right to suppose it.

The offices whence sensibility issues are, in fact to be found in the cerebrum ; those connected with movement are found in the cerebellum ; this we shall see farther on ; but nothing is so obscure as the after effects of these violent disturbances which disorder the workings of so delicate an apparatus ; and doctors even are often sadly perplexed to indicate the exact point where the damage has been inflicted. The changes which it leaves behind it are rarely visible, and its results are most capricious. Not only does it choose between the two halves of the body and the two systems of nerves, but

even there it takes and leaves, sometimes destroying the movement or the feeling only in certain places, while at other times it destroys them both only partially. The members in these cases retain a portion of their power, which may still be made use of by the will, but at what a sacrifice! This is neither more nor less than the paralysis of nightmare producing in reality during the waking state the imaginery effect of which we dream in the hours of sleep. The action of the nervous centre is not suppressed in this instance, it is only fettered and lowered. Who can tell us what kind of obstacles it encounters? Even in apparently extreme cases, when a limb, both powerless and insensible, seems entirely withdrawn from the action of the nervous centre, we cannot doubt but that some sense of feeling still remains. It is easy to note the moment when the decisive arrest of the electric circulation takes place, for then gangrene sets in.

The word I have just uttered is a terrible one, my dear child. I spoke to you a short time ago of the dead half and the living half. I then went a little too far. A muscle is not dead simply because it has lost its contractile power; and the proof that it is still living is that the fundamental sign of life, the continued renewal of its substance, still goes on in it. The chemical laboratory remains in activity; therefore the electric currents traverse it as hitherto, though less energetically, it is true. You can satisfy yourself on this point by taking hold of the hand of any person suffering from severe paralysis. A death-like coldness is already perceptible, although the arterial blood penetrates it as well as all other parts of the body, but the elements of combustion that it carries with it, and with which it meets there, cease to receive sufficient encouragement from the electric agent to maintain in it the ninety-eight

degrees Fahrenheit, of which we have already spoken. This hidden source of life—the chemical life—is lowered a notch. You might imagine you had come in contact with a reptile: I speak of a living one. Divide the last links that attach the cold hand to the centre from whence it receives its remnant of life, separate it from the arm, and decomposition will speedily ensue. When absolute paralysis shall silently sever these last links, there will be no occasion to cut off the limb; decomposition will take place in the hand, whether it be an appendage of the arm or not, and this is what is known by the expression gangrene, which is death, positive death, seizing upon part of a being still in life.

We will not pursue this subject any further; besides, we have finished the history of this nervous centre which holds the members so completely under its authority. Can you guess what thought came into my mind while I was showing you a hand reduced to the inferior life of a reptile? It was this, that the members of a reptile are better distributed than ours; at least, they are more independent; there life is not left so completely under the absolute action of a centre, that they cannot dispense with it. If you were to cut into the spinal marrow of a lizard in such a way as to intercept all communication between the head and the hind feet, the latter would still be able to move, and would be convulsed if you were to pinch them. In the reptile, life goes on in the provinces, though the latter be separated from the capital. If we descend lower still in the animal scale, we shall come into collision with organism where the capital is so unnecessary that there is none. This is one of the most distinctive laws of animal organization, that in proportion to its perfection, life tends to centralize itself more and more. You fully understand that I am just now

speaking of the life of relation ; and the human body, the masterpiece of the animal kingdom, is the one of all others in which, without contradiction, this centralisation is the most complete. Not long ago I said : "Society is like a man on a large scale ; it tends, by a natural inclination, to organize itself on the same plan as the human organisation." I greatly regret that these questions do not belong to our present subject, because in discussing them I should have had an opportunity of throwing light on a great quarrel, of which, one day or other, you will hear something. I shall only say a word about it here.

We belong to a country,* my dear child, which, as regards others, is to a certain extent what the human body is among other organisms, and which, into the bargain, suffers from these circumstances. The capital being gorged or surcharged paralyzes the provinces, and this is a disease we should endeavor to remedy ; but this does not prove that it is necessary to take away from it its title to social superiority by decentralizing its life. When the head is too full of blood, we put mustard-poultices to the feet. Why not act in a similar manner on the provinces ? Let them be exhorted to react upon the capital in the same way as moxas are applied to a benumbed limb to restore the electric circulation there, by making it rouse the brain. This is perfectly right ; it is combating the evil by remaining within the limits of the law of social life ; but to advise a return to their former isolation would be as absurd as to counsel our members to retrograde toward stages, over which nature has passed, in order to arrive at the point we have reached. People may say what they please, the lizard is a Girondin.

* The author, it will not be forgotten, is a Frenchman.

Ask some one else to explain to you what a Girondin is;* I avoid doing so for fear of being scolded. But how, I ask you, is it possible to dispense with politics when speaking to a queen of her government?

* Girondins was the name given to a political party which formed a section of the Second National Assembly of France called the "Legislative," in contradistinction to the first or "Constitutional," which framed the constitution of 1791. The members of this party were mostly from the departments of the West and South. They were republicans, and hostile to monarchy, and formed their notions of liberty on classical models.

CHAPTER XXXV.

THE INVOLUNTARY MOVEMENTS.

What would you say, my dear child, if, whilst you are moving about in your mother's room, answering her gentle voice and tender look, as naturally as you breathe, one of those beggar-women, whom you sometimes see in the streets, were all on a sudden to place herself between your parent and yourself, and seizing you roughly by the hand compel you to obey her vulgar commands?

I fancy I see you trembling from head to foot, vainly calling upon your mother to come to your assistance, as, dismayed by the termagant, you struggle in hopeless despair under the tyrannical restraint that tortures you. Well, then, a similar scene takes place within our bodies when the rude, coarse electricity of the pile, making an inroad in our members, violently repulses the friendly currents which are sent there by the will.

There are piles constructed expressly for this purpose. You take hold of a copper handle in each of your hands, and the current that rushes from one pole to the other passes through your body, it having suddenly been converted into a passage of communication between the two poles. The result of all this very clearly discloses the mysterious cause of muscular contraction. No matter how much you endeavor to prevent them, the hands instantly clench the copper handles as if some irresistible power issued from them; and they are certainly endowed

with a power, and one that we are all well acquainted with, inasmuch as it is that of electricity.

In this instance, the muscles are placed between two sources of electricity of different kinds, between two very different masters, each of which governs according to his own fashion. If we may be allowed to consider the brain as a sort of *animal* pile, whence proceed along the nerves currents of organic origin, civilized currents, if I may so express it, disciplined, guided in their course —be it by intelligence or instinct—the pile, in its turn may be compared in its action on the muscles to, excuse the expression, a kind of *mineral* brain projecting, in a straight line, currents of inorganic origin, which on their journey through our muscles conduct themselves like a band of unrestrained savages dashing straight ahead across a country. In the one case, as in the other, the muscular contraction is always caused by electricity, but what a difference in the procedure of the pile and that of the brain! The former invades the muscles all at once, causing them to contract simultaneously, in a riotous, painful manner as it passes along, and the antagonists of each pair of muscles pull, at the same time, in despair upon the bone, which does not know whom to obey. Instead of the regular transmission to and fro, effected with so much calmness and gentleness, when the brain issues her successive commands, the pile, like a stranger in the castle, by her blind and contradictory orders, produces nothing but universal confusion.

What have you to say of all this, my little friend? Did you expect, when I was giving you the history of Volta's frog, that we should end by finding the same thing repeated in ourselves. However, there is no use in our denying it. Electricity exercises the same action over us, whether it be produced from within or without;

and I have a proof of this, which struck me very forcibly the first time I became aware of it.

You know that we possess two sorts of nerves, those which carry information from the body to the brain, and create what is called sensation, the others which transmit the orders of the brain to all parts of the body, and preside over movement, that is to say, muscular contraction. Orders, then, and information, contractions and sensations, proceed from two different points in the regular working of life; orders pass from the centre to the extremities, information proceeds from the extremities to the centre. Now when the current of the pile invades a nerve, it immediately produces either a contraction or a sensation, according as it moves in the direction from the centre to the extremities, or from the extremities to the centre. Therefore I was not wrong in telling you just now, that under these circumstances the pile acts as a sort of brain to the muscle. The nervous filaments there do not mistake the agent; they act as electric conductors with it, exactly as they do with the brain, each in its own peculiar way. I will venture to add, that sensations and contractions are produced pell-mell, and at the same moment, provided the foreign current be energetic, no matter what may be its direction, It is a blind brute force, not understanding the word of command, but trampling it under foot the moment it has the power to do so.

We have in the history of nations, the counterpart of this foreign power coming and brutally assuming the place of the constituted and recognized government. This is called invasion, and I hope, my dear child, it may please God that you shall know it by name only. But invasion changes its name when it is the sovereign of a country himself who calls in a stranger to reduce

13*

his subjects to order, when he cannot succeed in doing so. It then becomes intervention ; and if we still wish to continue the comparison between the interior of our own little household and that of large governments, we shall recognize intervention there also.

You have not, I think, had time to forget what I said to you regarding paralysis, that revolt of the nervous system, currents of which cease to be subject to the will, or only obey it in an idle manner, like wearied or discontented subjects who treat with indifference whatever orders may be given to them. The will, betrayed by its ordinary servants, can then compel the muscles to contract in spite of themselves, by submitting them to the currents of the pile ; ever-willing servants, blind slaves who never dispute, resembling the Swiss of the King of Naples, who were so useful to him, that he could dispense with the fidelity of the Neapolitans. It is possible in this way to re-establish the electric circulation of paralyzed limbs, and apparently to imbue them with life for an instant. It is true that the life is but a foreign one momentarily borrowed from the external brain of which I have just spoken to you, and which, it is natural to expect, is condemned to disappear immediately communication is interrupted between the limb and the pile. But notice what a mysterious thing real life is, the life that has its centre in the true brain. The contact of foreign life is sometimes able to arouse it. The interior currents are themselves called into play, as if they were disposed to do their best on seeing the service of the muscles usurped by their younger brothers from without, and the impulse thus given persists long after the action of the pile has ceased. It may by repeated attempts even continue indefinitely. This is one of the means resorted to for the restoration of those afflicted with paralysis ;

and if you remember how those paralytics were cured and enabled to walk by a sudden effort of the will, you must, to a certain extent, be able to account for the wonderful effect the pile is sometimes capable of producing. Shock responds to shock ; it may be compared to the winding up of enfeebled springs, though how it is accomplished in either case we are unable to say.

It would not, however, do to trust this always. Intervention is dangerous in its nature, and the artificial life which is asked from it, occasionally breaks the springs instead of winding them up. We have heard of more than one example of partial paralysis being rendered complete by the intervention of the pile. We have also heard of princes whose last remnant of popularity has been destroyed by their appealing for the intervention of the stranger.

The most extraordinary effect that can by any possibility be made upon the animal machine by currents from a foreign source, is one that can never be of any service. It is precisely that observed by Volta on his dead frogs; it is the movement produced after death. Experiments have been made on bodies of which the executioner has just severed the head from the trunk. Death having overtaken these individuals whilst in the enjoyment of perfect health, they could be subjected to the currents of the pile while still possessing the necessary conditions to enable it, the pile, to play the part of the nervous centre which had just been destroyed. What spectacle can be more hideous than that of galvanized corpses playing at life, as it were, half raising themselves, twisting about, beating the air with their limbs, shaken for the last time by false convulsions, and then falling motionless the instant that the source of artificial life is

withdrawn from them. One may well call this the triumph of intervention ; truly man has never approached nearer to Nature in his endeavors to extract the secret of life from her bosom ; but the triumph has been a most fruitless one, and teaches us, better than anything else, how utterly powerless we are to enter the lists with the law which regulates all things.

I entitled this chapter " The Involuntary Movements." Here are some, undoubtedly, with which the will has nothing to do, and it would be somewhat difficult to set aside their claim to the epithet involuntary. I know of others the dependence of which is less authentic ; and as we never know what may be in store for us, I intend to enlighten you a little on the subject.

It is more than probable that you have heard people speak of hysterics, or nervous attacks. It is well known that the malady is peculiar to ladies, they having almost the entire monopoly of nervous disorders. Spiteful persons sometime go so far as to say that they constitute a great portion of their arsenal, but we are going to discuss the truth of these remarks. The fact is, that some physiological reason lies concealed beneath all this, and female nerves are in reality more difficult to keep in condition than are those of men.

This requires a word of explanation.

Nerves are something more than mere conductors in the human pile ; they are generators of electricity themselves, and in that capacity they perform an action peculiar to them. We are compelled to acknowledge this to be the case in animals possessing nerves and no brain, which may be compared to those barbarians of ancient Germany, when every man made war after his own fashion, and only depended upon his sword. The army of nerves within is subjected to the laws of a very severe

discipline, and quietly obeys the orders of a chief who may be said to hold the whole of them in his grasp. But no army is so well disciplined as not to be able to revolt when overmarched. Admirable as the arrangements are in the French army, it is not very long since it afforded us an example of this. It is true, it occurred among the Zouaves, the most nervous of its soldiers.

In moments of excitement, when vital activity is in excess, and electricity accumulates in the nerves, they are apt to work without orders, especially if from one cause or another there is general weakness, and consequently exhaustion of the brain. Then nervous attacks burst forth, agitating the members by involuntary movements, with so great an expenditure of power, that weak, delicate women have been known, whilst in this state, to struggle with vigorous men, afterward undergoing the inevitable punishment of having squandered their strength, and remaining for a long time in a state of extreme prostration. Now, it seems quite clear from all this, that the larger the nervous cords are compared with the brain, the easier it is for them to acquire the ascendancy over their chief; and this is just the case with women, who have, in general, in proportion to their size, larger nerves and smaller brains than men.

Do not, my dear child, conclude from all I have said, that in your future position of a grown-up lady, you are necessarily destined to suffer from nervous attacks on every occasion. No woman of any determination ever suffered from one of these attacks when she was really called upon to attend to any important business. I mentioned Semiramis to you when speaking of paralysis. Perhaps it would have been wiser to have reserved the story until now, for this is a case of armed rebellion; more alarming, I admit, yet easier to put down than the

simple refusal of the nerves to do their work, in the case of paralysis. These conditions may be said to represent a government contending with two obstacles ; on the one hand, the rebels have raised barricades, on the other, they obstinately refuse to pay the taxes.

A queen who has a will of her own is always certain in similar cases to keep her nerves in check, however large they may be, and on this account the rebellious movements of an attack of nerves are, properly speaking, only involuntary in a secondary point of view. Once allowed to take part in the insurrection, the nerves mock at the will, which, had it chosen, in the first instance, to act vigorously, would have obtained the ascendancy ; and so it is that man's free agency always renders him responsible for his actions.

We must not, however, pursue the subject too far. It was quite right that you should be taught something about these little mutineers, which are not so easy to control when they have once been allowed to have their own way. But whilst endeavoring to caution you against the error of letting them lead you captive, I would not have you to be unnecessarily severe upon those whom you may be called upon to witness suffering from these attacks. In each one of us there is an entire system of nerves independent of the action of the will—that of the nerves of the internal republic, which has its own nerves, —and when nervous affections proceed from this system, it would most assuredly be very cruel to judge harshly of those suffering from these attacks. I have had no occasion up to the present time to speak to you of these proud republicans ; they are quite distinct from the walking machine. Now that its history is completed, I must fill up a gap I was constrained to make in the preceding part. As we accompanied our "Mouthful of Bread" in

its various travels, we followed the example of tourists, travelling through Switzerland from canton to canton, delighting in the glaciers and the lakes without ever troubling themselves respecting the government of the country. It is true that the government does not occupy a very large space; neither does the government of the stomach, the heart, and the lungs occupy much space in us. For this reason I felt sure I might be allowed to skip over them without any considerable inconvenience. You must not, however, imagine the study is one to be despised; and, believe me, I should not have felt justified in passing over it silently if I had been able to enlarge upon it with you. Yet how was it possible to do so with a little child who had never learned anything about electricity?

CHAPTER XXXVI.

THE GREAT SYMPATHETIC NERVE.

These minor governments in the world of nutrition which we have passed by unnoticed, have frequently been as little regarded by others, who either never observed them at all, or considered them as quite unworthy of remark. I must in justice say they make very little show.

Buried in the hidden recesses of the body, between the vertebral column and the great organs of nutrition, there is a double row of small knots of nervous substance, bound together by a series of nerves running from one to the other in succession, from the neck to the base of the column. The whole appears like a sort of continuous cord with knots at certain distances, and for a long time this cord was looked upon as a dependency of the cerebral system with which it communicates by means of a certain number of nervous filaments. It had its assigned place among the great army of nerves, where it was known as the great sympathetic nerve; so well-chosen a name, that I prefer to retain it; and by and by, when we come to speak of the passions, you will see my reason for doing so.

The illustrious Bichat assigned its proper place to this great sympathetic nerve, and in this fact lies his best title to scientific glory. He was the first resolutely to proclaim in public what others had hitherto only ventured timidly to whisper, namely, that this pretended nerve, so far from being a subject, is the rival of the

brain; its colleague if you understand the term better. It is now acknowledged to be a mass of nervous centres, each of which possesses an independent life; a collection of little brains, if I may make use of the rather rash expression ventured on by some of the precursors of Bichat. It is, as the Swiss would say, the great council of this federative republic, which counterpoises the cerebral royalty within us. The nervous prolongations which unite these ganglia, this is the name given to these little brains, are only messengers employed to keep up a constant communication among them, as also the filaments proceeding from the vital centre by means of which a communication is established between the two great systems. As a messenger is only called upon to execute his commissions, he takes no part in the administration of affairs, therefore their respective independence remains intact.

Would you not feel somewhat curious to examine the presidents of our little republics rather more closely, my dear little girl? This is to be our last anatomical lesson, and you need not fear my making it too long. Do you not wish first of all to ask me of what shape are these ganglia? We are here in the land of liberty, where we shall not meet with that uniform symmetry, peculiar to regions under a monarchical government. Round, oblong, triangular, sometimes very voluminous, at others shrunk to almost nothing, they vary in shape and appearance, in the most capricious manner, from one end of the cord to the other; in one individual they are different from what we find in another, and those of the same pair most generally differ between themselves. Even their place and their number are subject to a thousand variations; sometimes they are to be found in places where usually there are none, at others they are vainly

looked for in parts where it is customary to meet with them. In this instance, Nature seems fully to avail herself of the liberty allowed her. And who can say but that the immense varieties of humor and temperament we meet with, may, in some degree, depend upon these caprices in the distribution of the nervous centres of the life of nutrition? You will be able to understand this better when we come to examine into their influence upon the actions of the moral life, as I propose doing at some future time.

The substance of the ganglia bears no resemblance to that of the spinal marrow and brain. It is a species of gelatinous pulp of a reddish gray color, lodged within an extraordinary fine cellular network, from whence bundles of white fibres issue, the extremities of which disappear in the pulp of the cells. The fibres of the ganglionic nerve do not form tight cords like those of other nerves ; the skein is loose, and every here and there its scattered threads are intertwined with those of the adjoining ganglia, to form what are called a plexus.* As I have selected a skein to illustrate my meaning, I will ask you to picture one to yourself that has become entangled in the winding, and some impatient little hand by dint of pulling at the threads in every direction, has drawn the whole into a ball. This will give you a tolerably clear idea of these plexus, which are easily distinguished from the ganglia, because they are composed of twisted fibres only, in which no trace of pulp is visible.

Now let us take a hasty glance at the principal details in the ganglionic world. It is too hidden a country for its topography to prove very interesting to you.

* Plexus in Latin signifies an interlacing.

We do not find all the ganglia on the line of the great sympathetic nerve. From those contiguous to the last pair of ribs, each generally has its own, bundles of fibres issue, the definitive expansion of which produces an inextricable confusion of intermingled nervous branches and small ganglia which sometimes separate, at others mixed up together in a manner baffling all description. All this assemblage of multiplied interweavings and stray ganglia form, beneath the diaphragm and the liver between the stomach and the vertebral column, a vast network, on which the anatomists have bestowed the poetic name of solar plexus, because, they say, it is a representation of the sun with its rays. We shall touch on the solar plexus again at some future time. The shock which the stomach sustains, a sensation so familiar to those who have suffered from great or sudden emotions, is due to this plexus ; and the ancients who placed the second seat of the soul there, its lower palace, if you like to call it so, were not far wrong in so doing. That part of us over which we have no control, is scarcely distinct from what is called the soul ; I mean the superior element of our nature.

The solar plexus envelops with its ramifications the aorta and the vessels which it sends to the diaphragm, the liver, and the digestive tube ; it seems arranged on the same plan as the arterial network, and the same may be said of all the nervous prolongations of the ganglia. It is in threading along the arteries, following the same path, that they almost always penetrate into the organs over which the ganglionic system rules. This invariable arrangement of the nervous apparatus peculiar to the life of nutrition, in my opinion sufficiently indicates wherein lies the secret of its power over its royal neigh-

bor ; it controls the blood which exercises immense authority over the brain.

Next to the solar plexus, the most important is the one placed close to the heart, at the exit of the aorta, and the elements of which are provided by the ganglia in the region of the neck ; it is called the cardiac plexus.* It was impossible for me to avoid mentioning this name; it would never do to pass silently over so great a personage as the one employed to govern the heart.

Speaking of government, I ought to tell you that his majesty the brain is represented in these popular assemblages of plexus, where the cerebral filaments are mixed up intimately with those of the ganglia ; it is by their means that whatever intelligence has seen elsewhere is revealed here, a necessary revelation indispensable to their intervention in the affairs of the life above. The royal messengers in their turn do not fail to create trouble there. They even sometimes seize upon the direction of affairs, as happened formerly in the case of the Polish diets, so jealous regarding the management of their country. Thus it is that certain men, so rare, it is true, that they are brought forward as examples in physiological books, have possessed the marvellous faculty of stopping at will, and according to their fancy, the beatings of this pre-eminent republican, the heart. A person possessing this power is in no way to be honored for having such a faculty, seeing that this phenomenon, so directly at variance with the recognised laws of nature, can only be explained on the supposition of a defective conformation of body. Nature, who is so capricious in her disposal of the ganglia, no doubt neglected to give sufficient development to their contingent

* Cardiac plexus, from the Greek word cardia, signifying a heart.

in the cardiac plexus of these individuals, and the cerebral fibres thought it a fine opportunity of showing their power, otherwise adieu to the royal will; it would vainly try to impose upon us if all were at their posts, and the proudest wills we have ever read of in history have never, so far as I know, prevailed over a cardiac plexus that was in proper order. When republics succumb, it can only be attributed to some error in the constitution.

Here I finish the history of our movements. It would have been incomplete if I had left out this chapter on internal movements, which, like the others, are performed by means of muscular contractions, determined by a nervous centre. Those muscles which work for the benefit of nutrition, are not exactly like those which the brain sets in motion; but I do not think it necessary to proceed further with our anatomical examination into this ganglionic world, which, you must agree with me, it was quite right you should know something of. We do not pretend to be blue stockings; it is quite enough that we have mastered (as an appendix to the history of the walking machine) the general description of those free powers which, in secret and in silence, keep all the parts of the eating machine in motion. This subject is so little known, that you may turn what you have learned to great advantage among your friends.

One word more before I take my leave.

I spoke to you the other day of centralisation. I am not quite sure whether I was right in doing so. At all events it is done; and, having begun the comparison between the social body and the human one, I am obliged to carry it out.

If it is true that each human being possesses within himself a model worthy of being consulted by all those

seeking for the best laws of social organisation—do not alarm yourself, I will put it before you in another form—if our body is a little society in such harmony as to serve as a standard for larger ones, we have here an explanation of that double instinct which leads nations to seek strength in centralisation, and freedom in decentralisation.

The domain of the brain: I know perfectly well where to look for it in governmental regions. The apparatus of relation is our Minister for Foreign Affairs, and the department of the muscles bears so strong an analogy to that of war, that military comparisons have continually presented themselves to my mind whilst we have been engaged in this study. It is evident that a guiding will is necessary. Nations could not do better than imitate Nature, who has placed all the powers of the body under one guidance, whose action is felt in every part when a struggle has to be maintained against the stranger. I do not require to recapitulate the conditions under which this supreme chief exercises its power, which becomes inert immediately the heart ceases to co-operate with it.

But other laws govern the interior life. The nutritive apparatus of a country, its commerce, its industry, the incessant labor of its citizens, by which public wealth is kept up, and let us also add the throbs of a national heart; all this the ganglionic system full plainly shows us requires to be left to itself. It would be a fine affair if the brain had to watch over the service of the stomach, or if, at its convenience, it regulated the movements of the Master who disposes of its life. Besides, how could it accomplish all this, and what would become of the poor body, if the least drowsiness attacked the universal centre? Happy is it for us, and do not let us be slow to own it, that Nature has armed herself against these en-

croachments of power, and only made them possible by some false step on her part. I have already told you that when government interferes with what does not concern it, it is the fault of the ganglia. Remember the history of the cardiac plexus.

With this, my dear child, we shall take leave of each other. We have now reviewed almost every part of the human machine, and I have little left to show you. That which remains to be seen is not the least curious part, being the outposts, so to speak, of our sentinels, that which, of all else within us, is the most artistically fashioned, the most exquisitely elaborated. Upon this will follow, perhaps, the most interesting of all ; I mean the invisible, that which is unseen. Adieu, then, my dear child, until the time when I shall have the pleasure of bringing before you the "History of the Senses and of Thought."

THE END.